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Signature

PATENT
Our Case No. 11336/108
(P00042US)

#29
6-21-03
Payton

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Gerald R. Stanley

Serial No.: 09/748,609

Filed: December 26, 2000

For: ACTIVE ISOLATED-INTEGRATOR LOW-PASS FILTER WITH ATTENUATION POLES

Examiner: T. Cunningham

Group Art Unit: 2816

APPEAL BRIEF

MAIL STOP APPEAL BRIEF-PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This Appeal is in response to the Final Office Action mailed December 23, 2002. A Notice of Appeal and the required fee were filed on March 21, 2003. A check in the amount of $430.00 is enclosed for the fees associated with filing this Brief in support of the Appeal, and for a one month extension of time. No other fees are believed required, however, should any additional fees be deemed necessary, the Commissioner is hereby authorized to charge any additional fees or credit any overpayment to Deposit Account No. 23-1925.

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I. Real Party In Interest

Harman International Industries, Incorporated is the real party in interest.

II. Related Appeals And Interferences

The undersigned is unaware of any other appeals or interferences that will directly affect, or be directly affected by, or have a bearing on the Board's decision in the pending appeal.

III. Status Of Claims

Claims 1-6 and 9-21 are pending. Claim 6 is allowed. Claim 19 would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claims. Claims 1-5, 9-18 and 20-21 are the subject of this appeal. The current state of Claims 1-21 are included in the Appendix.

IV. Status Of Amendments

Amendments by the Applicant filed with an after final office action response mailed on February 19, 2003 were not entered by the Examiner, and are one subject of this appeal. Specifically, new Figure 6 was amended to overcome the objections of the Examiner, and Claims 3 and 19 were amended to independent form based on the Examiner's indication of allowability. The proposed amendments are included in the office action response mailed February 19, 2003 that is include as Exhibit 1.

V. Summary Of Invention

As disclosed on pages 2-9 of the specification, the invention involves the inclusion of an isolated-integrator band-reject filter (20) into an active low-pass filter system. As illustrated in Figures 2 and 4, the active low-pass filter system comprises a low-pass filter circuit (22, 24, 26, 28, 30) and an isolated-integrator band-reject filter (20).

The low-pass filter circuit (22, 24, 26, 28, 30) includes a resistive forward signal flow branch. The low-pass filter circuit may be a Sallen & Key filter, a multiple feedback filter, a

state variable filter, or any other form of second order or higher active low-pass filter design. The isolated-integrator band-reject filter (20) is imbedded within the low-pass filter circuit (22, 24, 26, 28, 30).

The isolated-integrator band-reject filter (20) forms part of the resistive forward signal flow branch of the low-pass filter circuit (22, 24, 26, 28, 30). Accordingly, the isolated-integrator band-reject filter (20) is incorporated into the low-pass filter circuit (22, 24, 26, 28, 30) between an input terminal and an output terminal of the low-pass filter circuit (22, 24, 26, 28, 30). The isolated-integrator band-reject filter (20) includes three capacitors (C2, C4) of equal value, two resistors (R2, R6) of equal value and a tuning resistor (R3, R7) for tuning.

As illustrated in Figures 5 and 6, a power amplifier system (40) for driving a load (45) is also disclosed. The power amplifier system (40) includes a pulse width modulation circuit (42), an error amplifier and modulator circuit (43), a demodulation filter (47) and a feedback control loop. The error amplifier and modulator circuit (43) is connected to an input of the pulse width modulation circuit (42) and the demodulation filter (47) is connected to an output of the pulse width modulation circuit (42). The feedback control loop is connected to the error amplifier and modulator circuit (43) and the output of the pulse width modulation circuit (42). The feedback control loop includes a feedback demodulation filter (44). An isolated-integrator band-reject filter (20) is imbedded within the feedback demodulation filter (44).

VI. Issues

There are five issues presented in this appeal: (1) whether Claims 1, 2, 4-5, 13-18, 20 and 21 are anticipated pursuant to 35 U.S.C. § 102(b) by US Patent No. 5,635,871 to Cavigelli entitled "Low Phase Error Amplifying" (hereafter, "Cavigelli"); (2) whether Claims 9-12 are unpatentable pursuant to 35 U.S.C. § 112 first paragraph as being based on a non-enabling disclosure; (3) whether the proposed paragraph immediately following paragraph 46

in the Description of the Present Invention that was requested to be entered in Applicant's office action response mailed on November 8, 2002 (Exhibit 4) constitutes new matter; (4) whether proposed new amended Figure 6 that was requested to be entered in Applicant's after-final office action response mailed on February 19, 2003 (Exhibit 1) constitutes new matter; and (5) whether proposed amended Claim 3 that was requested to be entered in Applicant's after-final office action response mailed on February 19, 2003 (Exhibit 1) contains the language previously indicated by the Examiner as allowable subject matter.

VII. Grouping Of Claims

Claims 1-5, 7-18 and 20-21 do not stand or fall together. Accordingly, Applicant identifies the grouping of the Claims as follows:

Group I:	Claim 1, 13
Group II:	Claim 2
Group III:	Claims 16, 17
Group IV:	Claim 18
Group V:	Claims 5, 21
Group VI:	Claims 9, 10, 11, 12
Group VII:	Claim 3

VIII. Argument

A. The Statutory Standard

35 U.S.C. § 102(b) provides:

> A person shall be entitled to a patent unless — (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

A 35 U.S.C. § 102(b) rejection must be based on a single prior art reference that shows each and every element of the rejected claim. MPEP 2131, page 2100-68 ("A claim is anticipated only if each and every element as set forth in the claim is found, either expressly

or inherently described, in a single prior art reference." *Verdegaal Bros. v. Union Oil Co.*, 814 F.2d 628, 631 (Fed. Cir. 1987)). Accordingly, a 35 U.S.C. § 102(b) rejection must be overturned if a single prior art reference does not disclose each and every element recited in the claim.

B. Overview Of Cavigelli

Figure 12a of Cavigelli discloses an amplifier with three low-pass amplifier stages (7, 13 and 19) cascaded together. Cascaded with the amplifier stages (7, 13, 17) is a notch filter (202). The notch filter (202) provides filtering in a determined range of frequencies that are substantially above the operating frequencies of the amplifier. (Col. 8, lines 63-66) The notch filter may therefore eliminate high frequency noise caused by other sources.

C. Issues Raised On Appeal

1. Groups I-V (Claims 1, 2, 4-5, 13-18, 20 and 21) Are Patentable Over Cavigelli

a. Group I (Claims 1 and 13) is Patentable Over Cavigelli

Group I includes Claims 1 and 13. Claim 1 discloses an active low-pass filter system that includes a low-pass filter circuit and an isolated-integrator band-reject filter. The low-pass filter circuit includes a resistive forward signal flow branch. The isolated-integrator band-reject filter is embedded in the low-pass filter circuit to form part of the resistive forward signal flow branch. Claim 13 discloses an active low-pass filter system that includes a low-pass filter circuit having an input terminal and an output terminal. The active low-pass filter system also includes an isolated-integrator band-reject filter that is incorporated into the low-pass filter circuit between the input terminal and the output terminal.

The Examiner has asserted that the amplifier system of Figures 1 and 12(a) of Cavigelli is a low-pass filter circuit (amplifying stages 7, 13 and 19) and an isolated-integrator band-reject filter (notch filter 202). Attached as Exhibit 2 is the previously submitted declaration of Mr. James Wordinger indicating his belief that one skilled in the art

would interpret the term "isolated-integrator" as having the plain meaning described in the detailed description of Applicant's specification and the cited reference entitled *Tunable RC Null Networks*, Ralph Glasgal, October 1969 (*See* point 11). The plain meaning of "isolated-integrator" is defined in Figures 3A and 3B of the *Tunable RC Null Networks* article by Mr. Glasgal as well as Figure 1 and the supporting discussion in Applicant's specification.

The broadest reasonable interpretation of "isolated-integrator" therefore should consider the entire term within the plain meaning that one of skill in the art would understand the entire term to describe. Therefore, based on the plain meaning of the entire term "isolated integrator," the isolated-integrator band-reject filter is distinct from the notch filter disclosed in Cavigelli and the anticipation rejection is improper for this reason alone.

Since the entire term "isolated-integrator" has a plain meaning in the art, the entire term should be considered. Analogously, if one considers independently the terms "charge," "coupled" and "device," the device may be construed as device coupled into a circuit by a charge instead of a "charge-coupled device" (CCD) with the plain meaning known to those skilled in the art of an analog-to-digital converter. (*See The Illustrated Dictionary of Electronics*, p.110 (7^{th} ed., 1997) (attached as part of Exhibit 3) for definition of a charge-coupled device). The Examiner further asserts that the isolated-integrator band-reject filters disclosed in Applicant's specification and claims are merely "examples" of a type of filter, however, no other "examples" of isolated-integrator band-reject filters have been identified to support this assertion.

The Examiner agrees that the term "isolated-integrator" has the well-known meaning in the art described by Mr. Glasgal and Applicant's specification. (*See* Attachment to Advisory Action mailed March 13, 2003). Despite the acknowledgement of this well-known meaning, the Examiner, has dissected the plain meaning of the term "isolated-integrator" into two separate terms in order to assert that the notch filter disclosed by Cavigelli "inherently"

provides "integration" and "isolation." When understood based on its ordinary meaning, however, "isolated-integrator" is distinguished from the notch filter disclosed in Cavigelli because the term "notch filter" describes a broad class of filters. The term "isolated-integrator," on the other hand, describes a subclass of filter circuits as disclosed by Mr. Glasgal and Applicant's specification.

Even if one accepts, for purposes of discussion, that the terms "integration" and "isolation" should be considered separately, in spite of the plain meaning of the term "isolated-integrator" to those skilled in the art, Cavigelli still fails to anticipate the active low-pass filter system disclosed in Claims 1 and 13. Isolation is defined as "[t]he arrangement or operation of a circuit so that signals in one portion are not transferred to (nor affect) another portion." *The Illustrated Dictionary of Electronics*, P.375 (7th ed., 1997) (attached as Exhibit 3). In other words, the input is decoupled from the output. As an exhibit included with the office action response mailed November 8, 2003 (Exhibit 4), Applicant provided numerous examples of notch filters, none of which are isolated such that the input is decoupled from the output. Accordingly, signals provided to and from the example notch filters may affect other portions of a circuit, contrary to the isolated-integrator band-reject filter as claimed and detailed in Applicant's specification.

Applicant has specifically claimed the disclosed filter as an isolated-integrator band-reject filter. Cavigelli, on the other hand, simply discloses a notch filter. In an analogous example, one skilled in the art would not consider all amplifiers to <u>inherently</u> be buffers, unless the entire term "isolating amplifier" is used to identify the device. (*See The Illustrated Dictionary of Electronics*, p. 375 (7th ed., 1997) included as part of Exhibit 3 for a definition of an isolating amplifier). In Claims 1 and 13 Applicant has identified a band-reject filter as an isolated-integrator band-reject filter to include limitations within the claims indicated by

the plain meaning to those with skill in the art of the term isolated-integrator band-reject filter.

A notch filter does not necessarily include isolation, and the notch filter represented by the empty box in Figure 12a of Cavigelli clearly does not teach, suggest, or disclose isolation.

> To serve as an anticipation when the reference is silent about the asserted inherent characteristic, such gap in the reference may be filled with recourse to extrinsic evidence. Such evidence must make clear that the missing descriptive matter is necessarily present in the thing described in the reference, and that it would be so recognized by persons of ordinary skill.

Continental Can Co. v. Monsanto Co., 20 USPQ2d 1746, 1749 (Fed. Cir. 1991). The extrinsic evidence previously provided by the Applicant makes clear that isolation is not necessarily present in the notch filter of Cavigelli. Accordingly, Cavigelli does not teach each and every limitation of the isolated-integrator band-reject filter disclosed in Claims 1 and 13 whether the term "isolated-integrator" is considered according to the plain meaning of the whole term in the context of a band-reject filter, or when the term is inappropriately parsed into individual terms.

b. Group II (Claim 2) Is Patentable Over Cavigelli

Group II contains Claim 2. Claim 2 depends from Claim 1 and is therefore patentable over Cavigelli for at least the reasons given above in conjunction with Group I. In addition, Claim 2 is separately patentable because Claim 2 recites an additional limitation that is not disclosed by Cavigelli: that the isolated-integrator band-reject filter includes a resistor for tuning the band-reject filter. The notch filter of Cavigelli disclosed in Figure 12a is an empty box. The circuitry/topology of the notch filter is not taught by Cavigelli. Clearly, Cavigelli does not teach that the notch filter includes the specific limitation of a tuning resistor as in Claim 2. Accordingly, Claim 2 has separate, additional, independent reasons establishing patentability over Cavigelli.

c. Group III (Claims 16 and 17) Is Patentable Over Cavigelli

Group III contains Claims 16 and 17. Claims 16 and 17 depend from Claim 13. Claims 16 and 17 are therefore patentable over Cavigelli for at least the reasons given above in conjunction with Group I. In addition, Claims 16 and 17 are separately patentable. Claim 16 discloses additional limitations of a first and second resistor with an isolated-integrator band-reject filter electrically connected therebetween. Claim 17 discloses the limitation that one of the resistors of Claim 16 has a resistive value of zero. As the notch filter of Cavigelli disclosed in Figure 12a is an empty box, the circuitry/topology of the notch filter is not taught by Cavigelli. Clearly, Cavigelli does not teach the specific limitation that the notch filter is electrically connected between a first and second resistor as disclosed by Claim 16. Cavigelli also does not teach that one of the first and second resistors is zero impedance as disclosed by Claim 17. Accordingly, Claims 16 and 17 each have separate, additional, independent reasons establishing patentability over Cavigelli.

d. Group IV (Claim 18) Is Patentable Over Cavigelli

Group IV contains Claim 18. Claim 18 depends from Claim 13. Claim 18 is therefore patentable over Cavigelli for at least the reasons given above in conjunction with Group I. In addition, Claim 18 is separately patentable over Cavigelli because Claim 18 discloses that the isolated-integrator band-reject filter includes at least three capacitors with equal value and at least two resistor of equal value. As the notch filter of Cavigelli disclosed in Figure 12a is an empty box, the circuitry/topology of the notch filter is not taught by Cavigelli. Clearly, Cavigelli does not teach that the notch filter includes the specific limitations of at least two resistors of equal value and at least three capacitors of equal value as disclosed by Claim 18. Accordingly, Claim 18 has separate, additional, independent reasons establishing patentability over Cavigelli.

e. Group V (Claims 5 and 21)Iis Patentable Over Cavigelli

Group V contains Claims 5 and 21. Because Claims 5 and 21 are dependent from Claims 1 and 13 respectively, Claims 5 and 21 are patentable over Cavigelli for at least the reasons given above in conjunction with Group I. In addition, these claims are separately patentable over Cavigelli because Claims 5 and 21 both disclose the further limitation that the low-pass filter circuit is a state variable filter. Cavigelli on the other hand, teaches only that the cascaded low-pass amplifying stages provide zero phase error by phase shifting the output of the stages. Accordingly, Claims 5 and 21 each have separate, additional, independent reasons establishing patentability over Cavigelli.

2. <u>Group VI (Claims 9-12) Is Based On A Disclosure That Is Enabling</u>

a. Group VI (Claims 9-12) Are Enabled Pursuant To 35 USC §112

Group VI contains Claims 9-12. Claims 9-12 stand rejected pursuant to 35 USC §112 first paragraph based on a disclosure that is non-enabling. Claims 9-12 are supported by paragraph 11 on page 3 of the specification and the abstract. In addition, Claims 9-12 are supported by Figure 5 and paragraph 46 of the specification. Points 9(f) and 9(l) of the declaration of Mr. James Wordinger (Exhibit 2) clearly indicate that those skilled in the art would understand that paragraph 11 on page 3 and the abstract do enable the power amplifier of Claim 9. In addition, points 9(a), 9(b), 9(c), 9(d), 9(e), 9(g), 9(h), 9(i) and 9(j) of Mr. Wordinger's declaration indicate the understanding and knowledge of one skilled in the art that <u>enables</u> one skilled in the art, based on interpretation of the specification, to build the power amplifier described in Claims 9-12.

b. Copying Paragraph 3 On Page 11 Into The Detailed Description Did Not Add New Matter

Applicant has amended the specification by copying <u>verbatim</u> the language of paragraph 3 on page 11 to the detailed description section of the specification. The Examiner has object to this paragraph as new matter. As part of the amendment, and to show that no

new matter has been added, Applicant included the element numbers that were previously assigned in the original specification to the elements described in paragraph 3 on page 11. (*See* office action response mailed November 8, 2002 that is included as Exhibit 4). Section 2163.06 of the Manual of Patent Examination Procedure (MPEP) states "information contained in any one of the specification, claims or drawings of the application as-filed may be added to any other part of the application without introducing new matter." Clearly, Applicant has done nothing more than restate information already contained in the specification in another part of the specification, which therefore cannot be considered new matter.

c. Proposed New Amended Figure 6 Is Not New Matter

The Examiner has further indicated that the inclusion of paragraph 3 on page 11 to the detailed description stands together with the amended new Figure 6 that was also rejected as new matter. (*See* office action responses dated November 8, 2002 (included as Exhibit 4) and February 19, 2003 (included as Exhibit 1)). Amended new Figure 6 was added pursuant to 37 CFR §1.83(a) to simply illustrate the elements described in paragraph 3 on page 11 of the specification and hence Claims 9-12. The declaration of Mr. James Wordinger makes clear that those skilled in the art would interpret the existing specification and drawings to support amended new Figure 6. (*See* point 9, Exhibit 2), therefore entry of Figure 6 simply illustrates the existing disclosure at paragraph 3 on page 11 and as repeated in the detailed description.

The Examiner further contends that the specification does not disclose the "specific circuit arrangement and connections" illustrated in amended new Figure 6. Patent documents are not required to include subject matter known in the field of the invention, "to hold otherwise would require every patent document to include a technical treatise for the unskilled reader." S3 Inc. v. nVidia Corp., 259 F.3d 1364, 59 USPQ2d 1745 (Fed. Cir. 2001).

"Although an accommodation to the common experience of lay persons may be feasible, it is an unnecessary burden for inventors and has long been rejected as a requirement of patent disclosures." Id. The specification needs only to reasonably convey to one skilled in the art that the subject matter in question was in the possession of the inventor. *Fujikawa v. Wattanasin,* 39 USPQ2d 1895 (Fed. Cir. 1996). As indicated in the declaration of Mr. Wordinger, details such as the specific circuit arrangement and connections of amended new Figure 6 would be known by one skilled in the art, or understood based on the disclosure in the original specification and drawings. (*See* point 9 – Exhibit 2).

Claims 9-12 are based on the original specification and drawings and therefore, as shown above, the original specification and drawings enable the limitations disclosed by Claims 9-12. The paragraph in the detailed description and amended new Figure 6 simply clarify and complete the original specification and drawings. Later submitted material that "simply clarifies and completes" the prior disclosure is not new matter. *Triax Co. v. Hartman Metal Fabricators, Inc.*, 178 USPQ 142, 146 (2d Cir. 1973). Accordingly, Claims 9-12 should not be rejected pursuant to 35 USC § 112 first paragraph.

3. Group VII Is Allowable As Amended

Group VII contains Claim 3. Claim 3 stands objected to as being dependent upon a rejected base claim but would allowable if rewritten in independent form including all the limitations of the base claim and any intervening claim. Applicant has proposed amended independent Claim 3 that was requested to be entered in Applicant's after-final office action response mailed on February 19, 2003 (Exhibit 1). The Examiner has objected to proposed amended independent Claim 3. Clearly, proposed amended independent Claim 3 is nothing more than the combination of previously amended independent Claim 1 and previously amended dependent Claim 3 (*See* Appendix) specifically called for by the Examiner. Accordingly, proposed amended independent Claim 3 is allowable in its present form.

Conclusion

In summary, the 35 U.S.C. § 102(b) rejections against the claims of Groups I-V based on Cavigelli should be overturned. Cavigelli fails to teach or disclose each and every element of the claims and therefore cannot anticipate the claimed invention. In addition, the 35 U.S.C. §112 first paragraph rejection of the claims of Group VI should also be overturned, and the additional paragraph and Figure 6 should be entered in the case. The claims of Group VI are enabled by the specification as evidenced by the declaration of Mr. James Wordinger. The additional paragraph and Figure 6 are supported by the specification and should be entered as further evidenced by the declaration of Mr. James Wordinger. Finally, the proposed amendment of Claim 3 of Group VII should be indicated as allowable.

Dated: June 12, 2003

Respectfully submitted,

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Attachment: Exhibits 1, 2, 3 and 4

IX. Appendix

1. (Previously Amended) An active low-pass filter system including:

a low-pass filter circuit including a resistive forward signal flow branch; and

an isolated-integrator band-reject filter imbedded within the low-pass filter circuit, wherein the isolated-integrator band-reject filter forms part of the resistive forward signal flow branch.

2. (Original) The system of Claim 1, wherein the band-reject filter includes a resistor for tuning the band-reject filter.

3. (Previously Amended) The system of Claim 1, wherein the low-pass filter circuit includes a Sallen & Key filter.

4. (Original) The system of Claim 1, wherein the low-pass filter circuit is a multiple feedback filter.

5. (Original) The system of Claim 1, wherein the low-pass filter circuit is a state variable filter.

6. (Previously Amended) A power amplifier system for driving a load comprising:

a pulse width modulation power circuit creating ripple spectra;

an error amplifier and modulator circuit connected to an input of the pulse width modulation power circuit;

a demodulation filter connected between said pulse width modulation power circuit and the load;

a feedback control loop coupled to said error amplifier and modulator circuit and including:

an active low-pass filter;

a first resistive voltage divider circuit coupled between the output of said demodulation filter and a first input of said low-pass filter;

a feedback demodulation filter coupled to a second input of said low-pass filter and including at least one isolated-integrator band-reject filter; and

a second resistive voltage divider circuit coupled between the output of said pulse width modulation power circuit and said feedback demodulation filter.

7. (Cancelled)

8. (Cancelled)

9. (Previously Added) A power amplifier system for driving a load comprising:

a pulse width modulation power circuit having an input and an output;

an error amplifier and modulator circuit connected to the input of the pulse width modulation power circuit;

a demodulation filter connected to the output of the pulse width modulation power circuit;

a feedback control loop coupled to the error amplifier and modulator circuit and to the output of the pulse width modulation power circuit, the feedback control loop including a feedback demodulation filter, wherein an isolated-integrator band-reject filter is imbedded within the feedback demodulation filter.

10. (Previously Added) The system of claim 9, wherein the isolated-integrator band-reject filter includes a variable resistor for tuning the isolated-integrator band-reject filter.

11. (Previously Added) The system of claim 9, wherein the feedback demodulation filter is operable as a low-pass filter to remove pulse width modulated spectra from the feedback control loop, the pulse width modulated spectra produced by the pulse width modulation power circuit.

12. (Previously Added) The system of claim 9, wherein the feedback demodulation filter includes a resistive forward signal flow branch, the isolated-integrator band-reject filter being electrically connected within the resistive forward signal flow branch.

13. (Previously Added) An active low-pass filter system comprising:

a low-pass filter circuit having an input terminal and an output terminal; and

an isolated-integrator band-reject filter incorporated into the low-pass filter circuit between the input terminal and the output terminal.

14. (Previously Added) The active low-pass filter system of claim 13, wherein the low-pass filter circuit includes a resistive forward signal flow branch between the input terminal and the output terminal, the isolated-integrator band-reject filter incorporated into the resistive forward signal flow branch.

15. (Previously Added) The active low-pass filter system of claim 13, wherein the active low-pass filter system is at least a second order system.

16. (Previously Added) The active low-pass filter system of claim 13, wherein the low-pass filter circuit includes a first resistor and a second resistor, the isolated-integrator band-reject filter electrically connected between the first and second resistors.

17. (Previously Added) The active low-pass filter system of claim 16, wherein at least one of the first and second resistors has a resistive value of zero.

18. (Previously Added) The active low-pass filter system of claim 13, wherein the isolated-integrator band-reject filter includes at least three capacitors with equal value and at least two resistors with equal value.

19. (Previously Added) The active low-pass filter system of claim 13, wherein the low-pass filter circuit includes a Sallen & Key filter.

20. (Previously Added) The active low-pass filter system of claim 13, wherein the low-pass filter circuit includes a multiple feedback filter.

21. (Previously Added) The active low-pass filter system of claim 13, wherein the low-pass filter circuit includes a state variable filter.

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Sanders N. Hillis, Esq., Reg. No. 45,712

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RESPONSE PURSUANT TO 37 CFR §1.116
EXPEDITED PROCEDURE
GROUP ART UNIT 2816

PATENT
Case No. 11336/108(P00042US)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of
Gerald R. STANLEY
Serial No.: 09/748,609
Filed: December 26, 2000
For: ACTIVE ISOLATED-INTEGRATOR LOW-PASS FILTER WITH ATTENUATION POLES

Group Art Unit: 2816
Examiner: T. Cunningham

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REQUEST FOR RECONSIDERATION

BOX AF - EXPEDITED PROCEDURE
Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Applicant respectfully requests reconsideration of the rejections present in the Final Office Action mailed December 23, 2002. A check in the amount of $168.00 for two additional independent claims is enclosed. No additional fees are believed to be required at this time. However, should any additional fees be deemed necessary, please charge such fees to Deposit Account No. 23-1925. A duplicate copy of this Request is enclosed.

In the Claims:

Please enter amended claims 3 and 19 as indicated.

3. (Twice Amended) An active low-pass filter system including:

a low-pass filter circuit that includes a resistive forward signal flow branch and a Sallen & Key filter; and

an isolated-integrator band-reject filter coupled to the resistive forward signal flow branch.

19. (Amended) An active low-pass filter system comprising:

a low pass filter circuit having an input terminal and an output terminal, wherein the low-pass filter circuit includes a Sallen & Key filter; and

an isolated-integrator band-reject filter incorporated into the low pass filter circuit between the input terminal and the output terminal.

Drawings

As instructed by the Examiner, Applicant has revised new Figure 6 to include the isolated-integrator band reject filter. Applicant has submitted herewith a proposed amended new Figure 6 to the Official Draftsperson. A marked up version of originally submitted new Figure 6 is attached. Applicant respectfully requests the Examiner's approval of amended new Figure 6.

Status of the Claims

Claims 1-6 and 9-21 remain pending in the present application. Independent claim 6 has been indicated as allowed. Claims 3 and 19 are have been amended pursuant to 37 CFR §1.116 to be independent claims that include all the limitations of the base claim from which they previously depended. Applicant respectfully requests entry of amended claims 3 and 19 to place the application in better form in the event of an appeal. A marked up version of claims 3 and 19 is included as an attachment.

The Examiner has indicated in the official action mailed December 23, 2002 that claim 3 would be allowable if rewritten in independent form. Claim 19 was identified as rejected in the Official Action mailed December 23, 2002, however upon further discussion via telephone, the Examiner has indicated that the rejection of claim 19 was a typo, and that claim 19 would be allowable if re-written in independent form.

Applicant respectfully traverses and requests reconsideration of the rejected pending claims 1-2, 4-5, 9-18 and 20-21 in view of the following comments taken together with the Declaration Supporting Reconsideration of the Final Rejection submitted herewith as Exhibit 1.

The Declaration is from Mr. James Wordinger who is an electrical engineer with 24 years of experience in the field of electronics; electrical circuit design and electrical circuit operation related to electronic filters and audio power amplifier systems. Mr. James Wordinger is familiar with the general knowledge and experience of those skilled in the art of filters and

audio power amplifier systems. Mr. James Wordinger has concluded that amended new Figure 6 is supported by the specification of the application and does not introduce new matter. Mr. James Wordinger has further concluded that new amended Figure 6 is merely illustrative of paragraph 11 on page 3 of the specification and therefore does not introduce any new idea or concept to the application. Finally, Mr. James Wordinger has confirmed that the term "isolated integrator" has a plain meaning to those with ordinary skill in the art that is consistent with Applicant's specification and drawings.

New Matter

The Examiner has asserted that Applicant's amendment mailed on November 8, 2002 introduced new matter into the disclosure. Applicant's amendment added an additional paragraph to page 10 of the specification and a new drawing identified as Figure 6. Applicant respectfully disagrees that these amendments constitute new matter and respectfully requests the Examiner to reconsider this assertion.

One of ordinary skill in the art would recognize that the new paragraph is nothing more than a copy of existing paragraph 11 on page 3 of the original as-filed specification with the addition of element numbers. The added element numbers are the same element numbers used elsewhere in the specification to identify the elements discussed in paragraph 11 and in the new paragraph. Section 2163.06 of the Manual of Patent Examination Procedure (MPEP) states "information contained in any one of the specification, claims or drawings of the application as filed may be added to any other part of the application without introducing new matter." Clearly, Applicant has done nothing more than restate information already contained in the specification in another part of the specification, which therefore cannot be considered new matter.

One of ordinary skill in the art would regard the amended new Figure 6 simply as a visual form of that which is described by both paragraph 11 on page 3 and the new paragraph.

The Examiner has asserted that the new paragraph describes a feedback control loop that includes an active low-pass filter "having both a feedback demodulation filter and an isolated-integrator frequency rejecting network." *(emphasis Examiner's)* Applicant does not understand the Examiner's use of the term "both" since the term is not present in either paragraph 11 on page 3 nor the new paragraph. In fact, the language of these paragraphs is "an active low-pass filter having a feedback demodulation filter and an isolated integrator frequency-rejecting network. In one embodiment, the isolated-integrator frequency-rejecting network is an isolated-integrator band-reject filter." As detailed in the Declaration of Mr. James Wordinger attached as Exhibit 1, one of ordinary skill in the art would not understand this text to preclude the embodiment illustrated in amended new Figure 6.

The Examiner has also indicated that "it is clear that new Fig. 6 does not include a feedback control loop additionally having an isolated integrator frequency-rejecting network as expressly disclosed on page 3." Applicant has submitted amended new Figure 6 to include the isolated-integrator band-reject filter as part of the feedback demodulation filter within the feedback control loop. As described in paragraph 46 of page 10 of the specification, "the feedback demodulation filter includes at least one isolated-integrator band-reject filter 20." Accordingly, the feedback control loop depicted in Figure 6 includes the feedback demodulation filter of which the isolated-integrator frequency rejecting network is a part.

The Examiner further contends that "ones skilled in the art would interpret the discussion from lines 9-11 [paragraph 11 of page 3] as reading only on the circuit shown in Fig. 5." The Examiner has also asserted that "the specification does not, in any way, enable one skilled in the art as to how to make any/or the invention of Fig. 6." Again Applicant respectfully disagrees and requests reconsideration.

Clearly paragraph 11 of page 3 does not teach, suggest or disclose the filter 46 depicted in Figure 5. In addition, as previously discussed, Figure 6 is nothing more than an illustration of the elements discussed in paragraph 11 interconnected as described in paragraph 11. Further,

the attached Exhibit 1 Declaration of Mr. James Wordinger who Applicant submits is one of skill in the art factually rebuts the Examiner's assertions regarding amended new Figure 6.

For at least the foregoing reasons, Applicant respectfully requests the Examiner to withdraw his objection pursuant to 35 U.S.C. 132 of the new paragraph on page 10 and amended new Figure 6.

Claim Rejections pursuant to 35 U.S.C. §112, first and second paragraphs

Claims 9-10 were rejected pursuant to 35 U.S.C. §112, first and second paragraphs as being non-enabling and indefinite. The Examiner has maintained his assertions that the connection between the output of the demodulation filter and the feedback control loop as critical or essential to the practice of the invention and that without this feature it cannot be understood from the specification how the circuit will operate. Based on the Declaration attached as Exhibit 1, as well as the previously discussed reasons, Applicant respectfully asserts that those of ordinary skill in the art would understand how the circuit operates.

Patent documents are not required to include subject matter known in the field of the invention, "to hold otherwise would require every patent document to include a technical treatise for the unskilled reader." S3 Inc. v. nVidia Corp., 259 F.3d 1364, 59 USPQ2d 1745 (Fed. Cir. 2001). "Although an accommodation to the common experience of lay persons may be feasible, it is an unnecessary burden for inventors and has long been rejected as a requirement of patent disclosures." Id. As detailed in the US Patent included with the Exhibit 1 Declaration of Mr. James Wordinger, it is well known that feedback signals may be provided from the output of the amplifier. In addition, as clearly indicated in the detailed description, the embodiment illustrated in Figure 5 is simply one embodiment incorporating Applicant's invention. Accordingly, the embodiment described in paragraph 11, the Abstract and the new paragraph is merely another embodiment. Further, if the Examiner accepts amended new Figure 6 and/or the

new paragraph, Applicant submits that the rejection of claims 9-10 pursuant to 35 U.S.C. §112, first and second paragraphs is moot.

Claim Rejections pursuant to 35 U.S.C. §102(b)

Claims 1, 2, 4, 5, 13-18, 20 and 21 were rejected pursuant to 35 U.S.C. §102(b) as being anticipated by Cavigelli (U.S. Patent No. 5,635,871 hereinafter referred to as "Cavigelli"). Applicant respectfully disagrees and respectfully requests reconsideration for at least the following reasons.

The Examiner has asserted that Applicant's specification has not provided a specific definition for the term "isolated integrator" and that the term does not have a well-known meaning in the art. The Examiner has further asserted that "band-reject filters inherently provide integration and include isolation." Applicant respectfully disagrees that there is no meaning in the art for the term and further disagrees with the Examiners interpretation of the term.

The Examiner is referred to the reference cited by the Applicant in form PTO-1449 paper no. 4 or 5 entitled "Tunable RC Null Networks," by Ralph Glasgal, Oct 1969 issue of EEE, p. 70-74. In addition, the Examiner is referred to the Background section of Applicant's specification, Applicant's prior art Figure 1, and paragraph 23 of Applicant's detailed description. As clearly defined in Applicant's specification and the Glasgal prior art reference, the plain meaning of the technical term "isolated integrator" has well-known meaning in the art. "A technical term used in a patent claim is interpreted as having the meaning a person of ordinary skill in the field of the invention would understand it to mean." Dow Chemical Co. v. Sumitomo Chemical Co. , Ltd., 257 F.3d 1364, 59 USPQ2d 1609 (Fed. Cir. 2001).

In this case, the prior art in the field of the invention has clearly defined the plain meaning of the term "isolated integrator." In addition, Applicant has included Figure 1 and a detailed description in the application to reiterate the plain meaning of the term "isolated integrator." Applicant respectfully asserts that the dissection and application of definitions to

each word in the term "isolated integrator" is unwarranted and does not comply with the objective test of what one skilled in the art would understand the term to mean. Accordingly, Applicant respectfully requests the Examiner to reconsider the to 35 U.S.C. §102(b) rejection of claims 1 and 13.

The Examiner is also respectfully requested to consider the dependent claims of the pending application. As the Examiner is already aware, the notch filter (202) of Fig. 12A of Cavigelli is illustrated as an empty box. In addition to failing to teach that the notch filter of Cavigelli is an isolated integrator band-reject filter, Cavigelli also fails to teach the elements disclosed in the dependent claims of the pending application as Applicant discussed in the previous Official Action Response mailed November 8, 2002. An excerpt from the November 8, 2002 Office Action Response is reproduced below to again request consideration of the cited dependent claims:

> Further, neither the notch filter 202 or any of the amplifying stages 7, 13 and 19 of Cavagelli disclose a tuning resistor as disclosed in claim 2; a resistive forward signal flow branch as disclosed in claim 14; a first resistor and a second resistor with the isolated integrator band-reject filter connected therebetween as disclosed by claim 16; a resistive value of zero as disclosed by claim 17; or at least three capacitors and at least two resistors of equal value as disclosed by claim 18. In fact, <u>none</u> of the cited prior art references teach, suggest or disclose the isolated integrator band-reject filter disclosed in claims 1 and 13, or any of the elements disclosed by claims 2, 14, 16, 17 or 18.

For at least the foregoing reasons, Applicant respectfully requests the Examiner to remove the rejection pursuant to 35 U.S.C. §102(b) of independent claims 1 and 13 and dependent claims 2, 14, 16, 17 and 18. Alternatively, since dependent claims 2, 4-5 and 14-18,

dependent claims 2, 14, 16, 17 and 18. Alternatively, since dependent claims 2, 4-5 and 14-18, 21-22 depend from respective independent claims 1 and 13, removal of the 35 U.S.C. §102(b) rejection of these dependent claims is respectfully requested.

Applicant believes that claims 1, 2, 4, 5, 9-18, 20 and 21 are allowable in their present form and that this application is in condition for allowance. Accordingly, it is respectfully requested that the Examiner so find and issue a Notice of Allowance in due course. Should the Examiner deem a telephone conference to be beneficial in expediting allowance of this application, the Examiner is invited to call the undersigned attorney at the telephone number listed below.

Respectfully submitted,

Sanders N. Hillis
Attorney Reg. No. 45,712

Attachments: Version with Markings to Show Changes Made (p. 10)
Marked up version of Figure 6
Exhibit 1 - Declaration of Mr. James Wordinger (19 pages)

BRINKS HOFER GILSON & LIONE
One Indiana Square, Suite 1600
Indianapolis, Indiana 46204-2033
Telephone: (317) 636-0886
Fax: (317) 634-6701

VERSION WITH MARKINGS TO SHOW CHANGES MADE

Please amend Claims 3 and 19 as follows:

3. (Twice Amended) An active low-pass filter system including:

a low-pass filter circuit that includes a resistive forward signal flow branch and[The system of Claim 1, wherein the low-pass filter circuit includes] a Sallen & Key filter[.]; and

an isolated-integrator band-reject filter coupled to the resistive forward signal flow branch.

19. (Amended) An active low-pass filter system comprising:

a low pass filter circuit having an input terminal and an output terminal[The active low-pass filter system of claim 13], wherein the low-pass filter circuit includes a Sallen & Key filter[.]; and

an isolated-integrator band-reject filter incorporated into the low pass filter circuit between the input terminal and the output terminal.

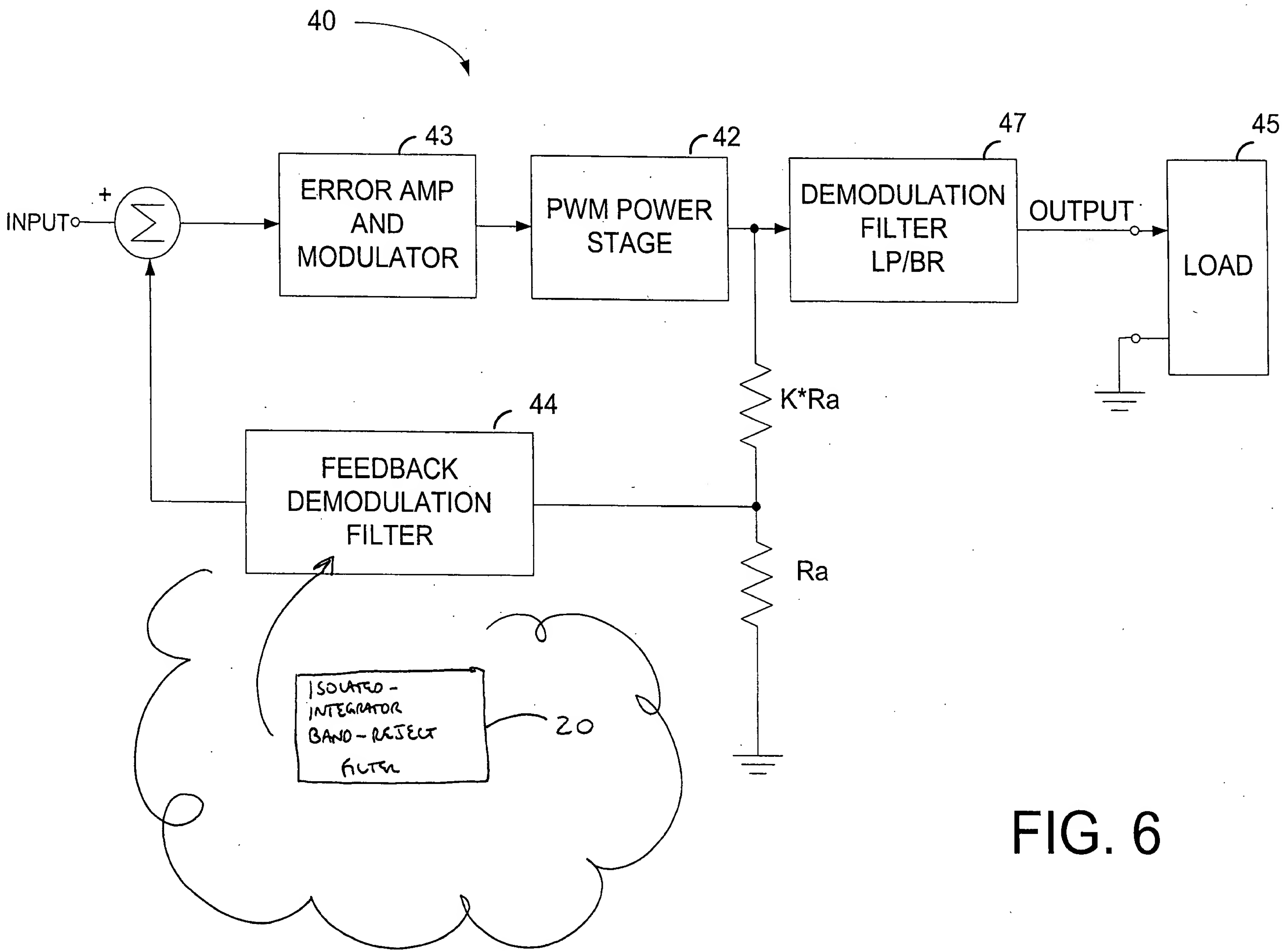
40
INPUT
+
Σ
43
ERROR AMP
AND
MODULATOR
42
PWM POWER
STAGE
47
DEMODULATION
FILTER
LP/BR
OUTPUT
45
LOAD
K*Ra
Ra
44
FEEDBACK
DEMODULATION
FILTER
ISOLATED-
INTEGRATOR
BAND-REJECT
FILTER
20

FIG. 6

Certificate Under 37 CFR 1.8(a)
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Sanders N. Hillis, Esq., Reg. No. 45,712

RESPONSE PURSUANT TO 37 CFR §1.116
EXPEDITED PROCEDURE
GROUP ART UNIT 2816

PATENT
Case No. 11336/108 (P00042US)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	)	Group Art Unit: 2816
Gerald R. STANLEY	)	Examiner: T. Cunningham
Serial No.: 09/748,609	)	
Filed: December 26, 2000	)	
For: ACTIVE ISOLATED-INTEGRATOR LOW-PASS FILTER WITH ATTENUATION POLES	)	

TRANSMITTAL OF AMENDED NEW FORMAL DRAWING

BOX AF - EXPEDITED PROCEDURE
Commissioner for Patents
Washington, D.C. 20231

Sir:

Applicant submits herewith amended new formal drawing Figure 6 to the Official Draftsperson. A marked up copy of Figure 6 is included as an attachment to the Request for Consideration After Final included herewith.

Respectfully submitted,

Sanders N. Hillis
Attorney Reg. No. 45,712

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One Indiana Square, Suite 1600
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Telephone: 317-636-0886
Facsimile: 317-634-6701

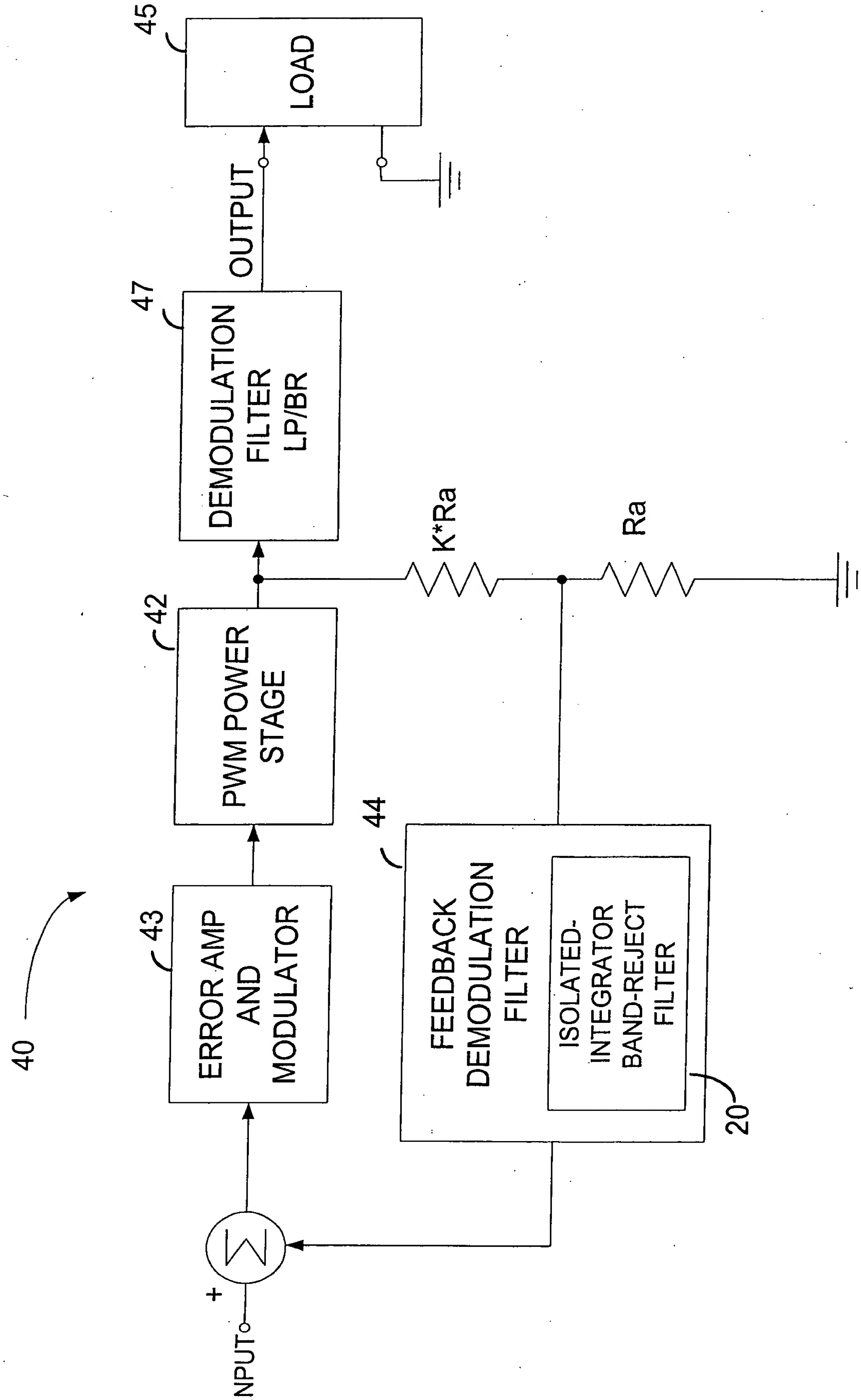
40
INPUT
+
43
ERROR AMP AND MODULATOR
42
PWM POWER STAGE
47
DEMODULATION FILTER LP/BR
OUTPUT
45
LOAD
K*Ra
Ra
44
FEEDBACK DEMODULATION FILTER
ISOLATED-INTEGRATOR BAND-REJECT FILTER
20

FIG. 6

Certificate Under 37 CFR 1.8(a)
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Sanders N. Hillis, Esq., Reg. No. 45,712

RESPONSE PURSUANT TO 37 CFR §1.116
EXPEDITED PROCEDURE
GROUP ART UNIT 2816

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Gerald R. STANLEY	)	Examiner: T. Cunningham
Serial No.: 09/748,609	)	
Filed: December 26, 2000	)	
For: ACTIVE ISOLATED-INTEGRATOR LOW-PASS FILTER WITH ATTENUATION POLES	)	

DECLARATION SUPPORTING RECONSIDERATION OF FINAL REJECTION

I, James Wordinger hereby declare that:

1. I am an electrical engineer with 24 years of experience in the field of electrical circuit design and electrical circuit operation related to filters and audio power amplifier systems. I graduated from Purdue University in 1979 with a degree in electrical engineering. Upon graduation, I was employed by Crown International as an electrical engineer and have worked as lead engineer on several audio amplifier programs including the MT, MA, CT, MR, K, and CTs amplifier series, representing sales of over $500,000,000 to date. Currently, I am employed by Crown Audio, Inc. a subsidiary of Harman International Industries, Inc. My title is currently Senior Design Engineer. My job responsibilities include product definition, circuit design, analysis, and all aspects of product implementation in a modern team based environment. I am identified as an inventor of D394858 United States patent.

2. Since 1979 I have worked with about 30 designers, engineers and other technicians who are involved in the design and application of filters and/or audio power amplifier

systems. This experience has provided me with the opportunity to observe others working in this field of endeavor. As a result of this experience, I believe I am well acquainted with a sufficient number of people to assess the skill level of persons of ordinary skill in the art of the design and application of filters and/or audio power amplifier systems.

3. I have reviewed US Patent Application Serial No. 09/748,609 filed on December 26, 2000 and associated Figures 1 through 5.

4. I have reviewed the new paragraph that was submitted in the Response to Official Action mailed to the US Patent Office on November 8, 2002.

5. I have reviewed amended new Figure 6 that it is my understanding will be submitted as part of a Request for Reconsideration that will be filed in response to an Official Action mailed December 23, 2002.

6. I have reviewed US Patent No. 4,178,556 to Attwood issued on December 11, 1979 that is attached as Exhibit A.

7. I have reviewed the definition of "feedback" from The Illustrated Dictionary of Electronics, 275 (7th ed., 1997) attached as Exhibit B and concur that the definition is accurate.

8. I have reviewed the paper entitled "Tunable RC Null Networks," by Ralph Glasgal, from the Oct 1969 issue of EEE, p. 70-74 that is attached as Exhibit C.

9. I believe that a person of ordinary skill in the art could interpret the disclosure of amended new Figure 6 to be enabled by the existing specification and drawings without undue experimentation based on the following facts:

   a) It is well known to those of ordinary skill in the art to include a feedback control loop to control the operation of a power amplifier system as taught by Exhibit A and B.

   b) It is also well known to those of ordinary skill in the art to include a filter mechanism in a feedback control loop of a power amplifier as further taught by Exhibit A.

   c) It is also well known to those of ordinary skill in the art to provide a feedback signal derived locally at the output of a power amplifier system as taught in Exhibit A, without including an additional feedback signal derived remotely near a load.

d) Those of ordinary skill in the art would understand that paragraph 46 on page 10 describes "another embodiment" of the invention as merely one example of how to practice the invention.

e) Those of ordinary skill in the art would understand that paragraph 46 of page 10 discusses how to remove pulse width modulated (PWM) spectra from the feedback signals using a feedback demodulation filter that includes an isolated-integrator band-reject filter.

f) Those of ordinary skill in the art would understand that paragraph 11 on page 3 and the Abstract of the above-referenced patent application both teach the interconnection of the described components to form a power amplifier system that is illustrated in amended new Figure 6. More specifically:

> 1) Those of ordinary skill in the art would understand that paragraph 11 of page 3 describes a power amplifier system that includes a pulse width modulation circuit creating ripple spectra and a feedback control loop coupled to the pulse width modulation circuit.
>
> 2) Those of ordinary skill in the art would understand that paragraph 11 of page 3 also describes that the feedback control loop includes an active low-pass filter having a feedback demodulation filter and an isolated-integrator frequency rejecting network, which is an isolated-integrator band-reject filter in some embodiments.

g) As is well known to those of ordinary skill in the art, and also taught by Exhibits A and B, a feedback control loop provides feedback signals to control an input to a power amplifier system.

h) As is also well-known to those of ordinary skill in the art, ripple spectra (or PWM spectra) as well as other noise in the feedback signals may affect the performance of feedback control.

i) Those of ordinary skill in the art would understand that the feedback demodulation filter when included in the feedback control loop will provide feedback control signals that do not include PWM spectra and can be used to control the input.

j) Those of ordinary skill in the art would understand that if removal of the PWM spectra from a feedback signal is desired, the teachings of the above-referenced patent application teach the addition of the feedback demodulation filter in the feedback control loop to perform this function.

k) Those of ordinary skill in the art would also understand that the above-referenced patent application teaches the addition of the isolated-integrator band-reject filter as part of the feedback demodulation filter.

l) Those of ordinary skill in the art would further understand that neither the paragraph 11 on page 3 nor the abstract teach that an output of the demodulation filter (remote feedback signal) to the feedback control loop is required or essential to the operation of a power amplifier system. This fact is well-known to those of ordinary skill in the art as evidenced by Exhibit A, where a feedback signal is derived locally at the output of the amplifier without an additional remotely derived feedback signal at the load.

10. I believe that those of ordinary skill in the art would understand that a power amplifier system that includes in a feedback control loop a feedback demodulation filter having an isolated-integrator band reject filter will operate to control an input to the power amplifier system without an additional feedback signal derived from an output of a demodulation filter.

11. I believe that those of ordinary skill in the art would understand that the term "isolated-integrator" has the plain meaning which is described in Exhibit C. Further I believe that those of ordinary skill in the art would understand that the special meaning of the term "isolated-integrator" as used in the above-referenced patent application and claims is the same plain meaning described by Exhibit C.

It is my belief that amended new Figure 6 and the new paragraph previously added by amendment are both inherently disclosed by the as-filed patent application, and do not constitute the addition of any new idea or concept.

I hereby declare under penalty of perjury that the foregoing is true and correct.

2/18/03
Date:

James Wordinger
James Wordinger

Attachments: Exhibit A (US Patent No. 4,178,556)
Exhibit B (Electronic Dictionary excerpt - 3 pages)
Exhibit C ("Tunable RC Null Networks," by Ralph Glasgal, from the Oct 1969 issue of EEE, p. 70-74)

EXHIBIT "A"

U.S. Patent No. 4,178,556

United States Patent [19]

Attwood

[11] 4,178,556

[45] Dec. 11, 1979

[54] CLASS D AMPLIFIER SYSTEM

[76] Inventor: Brian E. Attwood, Sestri 49, Smithbarn Horsham, Sussex RH13 6DS, England

[21] Appl. No.: 897,699

[22] Filed: Apr. 19, 1978

[30] Foreign Application Priority Data

Apr. 22, 1977 [JP] Japan .... 52/50399[U]

[51] Int. Cl.² H03F 3/38

[52] U.S. Cl. .... 330/10; 330/251; 330/207 A; 330/302

[58] Field of Search .... 330/10, 251, 207 A, 330/302

[56] References Cited

U.S. PATENT DOCUMENTS

4,021,745 5/1977 Suzuki et al. 330/10

4,059,807 11/1977 Hamada 330/10

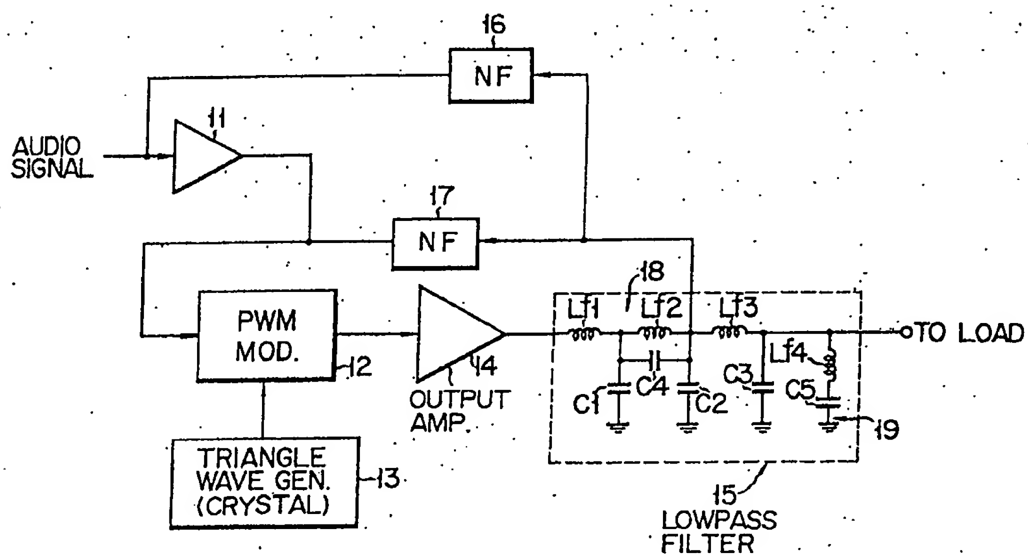
Primary Examiner—Lawrence J. Dahl

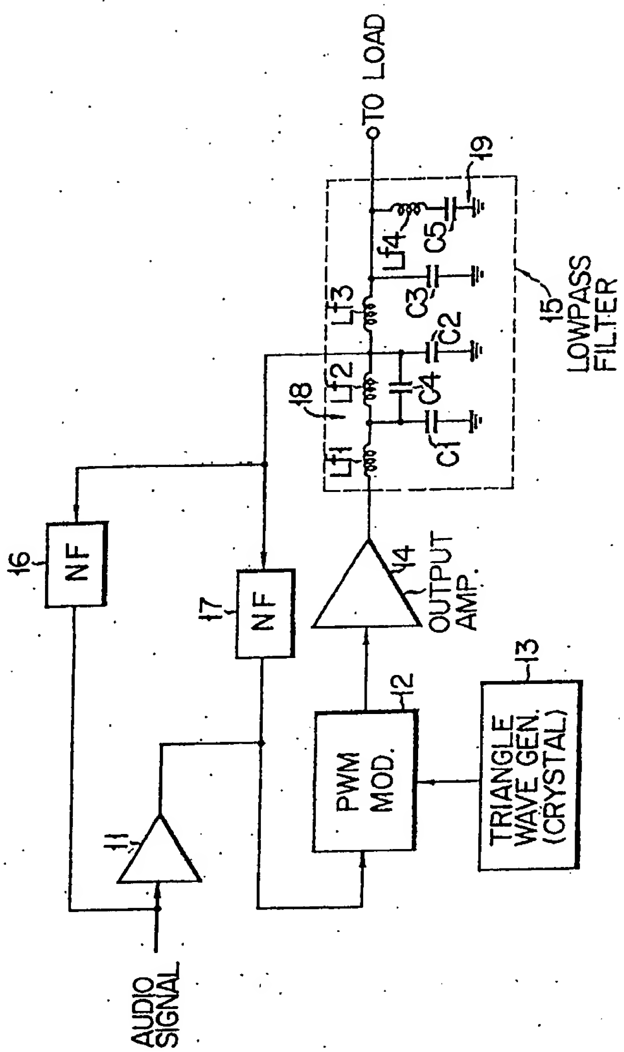
Attorney, Agent, or Firm—Harris, Kern, Wallen & Tinsley

[57] ABSTRACT

In a Class D amplifier system comprising a pulse width modulator for pulse width modulating with an audio signal a carrier signal having a frequency higher than that of the audio signal, an output switching amplifier connected to the modulator, and a lowpass filter connected to the output amplifier to supply a demodulated audio signal to a load in which a trap circuit resonant at a carrier signal frequency is provided in the lowpass filter to permit part of an output signal from the trap circuit which is free from a carrier signal component to be negative-fed back to the pulse width modulator.

4 Claims, 1 Drawing Figure




TO LOAD
19
LOWPASS FILTER
15
Lf1
Lf2
Lf3
Lf4
C1
C2
C3
C4
C5
18
NF
16
NF
17
OUTPUT AMP.
14
PWM MOD.
12
TRIANGLE WAVE GEN. (CRYSTAL)
13
11
AUDIO SIGNAL

CLASS D AMPLIFIER SYSTEM

This invention relates to a Class D amplifier.

A Class D amplifier is known as a high efficient amplifier, which pulse width modulates with an audio signal a pulse signal having a frequency higher than that of an audio signal and demodulates a resultant pulse modulated signal to cause a loudspeaker to be driven.

The object of this invention is to provide a Class D amplifier system of low distortion.

According to this invention there is provided a Class D amplifier system comprising an audio amplifier for amplifying an audio signal; a carrier signal source; a pulse width modulator for pulse width modulating a carrier signal from the carrier signal source by an output signal of the audio amplifier; an output amplifier connected to the pulse width modulator for amplifying a pulse width modulated signal; a lowpass filter connected to the output amplifier to apply a recovered audio signal to a load; a trap circuit arranged in the lowpass filter to resonate at a carrier signal frequency; and means for permitting part of an output voltage from the trap circuit to be negative-fed back to the pulse width modulator.

This invention can be more fully understood from the following description when taken in connection with the accompanying drawing, in which:

The FIGURE is a schematic block diagram showing a Class D amplifier system according to this invention.

In a Class D amplifier, as will be shown in the drawing, an audio input signal is amplified by an amplifier 11 and then it is supplied to a pulse width modulator (PWM) 12. A triangle-wave carrier signal with a frequency of, for example, 430 KHz is supplied from a triangle-wave oscillator 13 to the pulse width modulator 12. The pulse width modulator 12 may be constructed of a level comparator and adapted to compare the level of the audio signal with that of the reference triangle-wave signal to generate a rectangular-wave pulse width modulated signal whose pulse width varies according to the instantaneous amplitude level of the modulating audio signal. The pulse width modulated signal is amplified by an output amplifier 14. The output amplifier 14 may be constructed of a pair of switching devices which are alternately switched ON and OFF in response to the pulse width modulated input signal. A lowpass filter 15 is connected between the output amplifier 14 and a load such as a loudspeaker, and supplies to the load a demodulated audio signal. Part of the output voltage is taken out of the lowpass filter and then negative-fed through a negative feedback circuit network (NF) 16 back to the audio amplifier 11 and through a negative feedback circuit network 17 back to the pulse width modulator 12, thereby making the system stable and attaining an improvement of distortion.

In the drawing, the lowpass filter is comprised of choke coils Lf_1 and Lf_3 and capacitors C_1, C_2 and C_3 and adapted to eliminate the ripple component of the carrier signal frequency of the oscillator 13. If the ability of the lowpass filter to eliminate high frequency ripple component is insufficient, such high frequency ripple component is fed back to the audio amplifier 11 and pulse width modulator 12, thus giving a cause for distortion.

When, for example, high frequency ripple component is fed back to the pulse width modulator, it would be impossible to obtain a desired pulse width according to the instantaneous amplitude of the audio signal.

In this invention, a parallel resonance circuit, i.e. a trap circuit, is provided to sufficiently eliminate a high frequency ripple component. That is, the parallel resonance circuit 18 comprising a choke coil Lf_2 and capacitor C_4 and adapted to resonate at the output frequency of the oscillator 13 is connected between the choke coils Lf_1 and Lf_3. Part of the output voltage is taken out of a junction between the choke coils Lf_3 and Lf_2 and fed back to the audio amplifier 11 and pulse width modulator 12 through the negative feedback circuits 16 and 17. Since, due to the trap circuit, high frequency ripple component can be sufficiently eliminated, object of the negative feedback can be fully attained.

Further, if the oscillator 13 is constructed of a crystal controlled oscillator of which the oscillation frequency is sufficiently stable, then it becomes possible to elevate the selectivity of resonance circuit 18. As a result, the high-frequency ripple eliminating capability is more enhanced.

At the output side of the lowpass filter 15 a series resonance circuit 19 may be provided which comprises a choke coil Lf_4 and capacitor C_5 and resonates by the carrier signal frequency. By provision of the trap circuit 19, high frequency ripple component can be prevented from being radiated externally thorugh connection lines between the lowpass filter and the load.

What is claimed is:

1. A Class D amplifier system comprising:
   - an audio amplifier for amplifying an audio signal;
   - a carrier signal source;
   - a pulse width modulator for pulse width modulating a carrier signal from said carrier signal source by an output signal of said audio amplifier;
   - means connecting the output of said audio amplifier and the output of said carrier signal source to said pulse width modulator as inputs;
   - an output amplifier having an input connected to the output of said pulse width modulator for amplifying a pulse width modulated signal;
   - a low pass filter having an input connected to the output of said output amplifier to apply a recovered audio signal to a load;
   - a trap circuit arranged in said lowpass filter to resonate at a carrier signal frequency; and
   - negative feed-back circuit means connecting an output voltage from said trap circuit as input to said pulse width modulator.

2. A Class D amplifier system according to claim 1, in which said carrier signal source is comprised of a crystal oscillator.

3. A Class D amplifier system according to claim 1, in which said trap circuit is a parallel resonance circuit comprising a coil and a capacitor which is connected between the output of said output amplifier and said load.

4. A Class D amplifier system according to claim 1, further comprising a series resonance circuit connected between the output of said lowpass filter and ground and adapted to resonate at the carrier signal frequency.

* * * * *

EXHIBIT "B"

Excerpt from

The Illustrated Dictionary of Electronics, 7th Ed. (3 pages)

The Illustrated Dictionary of Electronics

Seventh Edition

Stan Gibilisco
Editor-in-Chief

McGraw-Hill

New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto

Library of Congress Cataloging-in-Publication Data

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621.381'03—dc21 97-9081
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1 2 3 4 5 6 7 8 9 0 FGR/FGR 9 0 2 1 0 9 8 7

ISBN 0-07-024186-4

The sponsoring editor for this book was Scott Grillo, and the production supervisor was Pamela Pelton. It was set in Bookman by Lisa Mellott through the services of Barry E. Brown (Broker—Editing, Design and Production).

Printed and bound by Quebecor/Fairfield.

of bodies and materials to weaken, deform, or fracture under repeated strain.

fault 1. A defective point or region in a circuit or device. 2. A failure in a circuit or device.

fault current 1. A momentary current surge. 2. A leakage current.

fault finder A troubleshooting instrument or device (e.g., a multimeter).

fault resilience 1. A design scheme for an electronic or computer device or system so that if a component or circuit fails, the system will continue to operate, although perhaps at reduced efficiency. The operator is notified of the problem so that it can be repaired with minimal downtime. 2. In a computer system, the property of being as nearly sabotage-proof as possible.

fault tolerance Total redundancy in an electronic or computer system so that if a component or circuit fails, the system will continue to function at full efficiency. Every component has a backup that automatically takes over in case of failure. The operator is notified of the problem, so the defective part or circuit can be replaced while its backup keeps the circuit working continuously at 100-percent capacity.

Faure plate A storage battery plate consisting of a lead grid containing a chemical electrolytic paste.

fax Abbreviation of FACSIMILE.

fc Abbreviation of FOOT-CANDLE.

f_c Abbreviation of CARRIER FREQUENCY.

FCC See FEDERAL COMMUNICATIONS COMMISSION.

f_{co} Abbreviation of CUTOFF FREQUENCY.

F connector A type of antenna feedline connection especially common on television receivers and videocassette recorders.

F display See F SCAN.

FDM Abbreviation of *frequency-division multiplex*.

FE Abbreviation of FERROELECTRIC. See FERROELECTRICITY.

Fe Symbol for IRON.

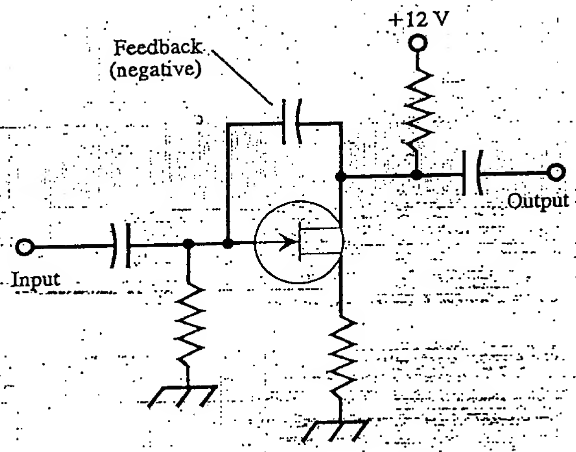
feasibility study The procedures for evaluating the potential gains in applying a computer system to a job or to an organization's process, or in modifying or replacing an existing system.

FEB Abbreviation of FUNCTIONAL ELECTRONIC BLOCK.

Federal Communications Commission Abbreviation, FCC. Established in 1934, the U.S. Government agency that regulates electronic communications. The FCC succeeded the Federal Radio Commission (FRC), which was established in 1927; the FRC succeeded the Radio Division of the Bureau of Navigation in the Department of Commerce, whose jurisdiction over radio began in 1912.

feed 1. To supply power or a signal to a circuit or device. 2. The method of supplying such a signal or power. See, for example, PARALLEL FEED and SERIES FEED. 3. To cause data to be entered into a computer for processing.

feedback 1. The transmission of current or voltage from the output of a circuit or device back to the input, where it interacts with the input signal to modify operation of the device. Feedback is positive when it is in phase with the input, and is negative when it is out of phase. 2. To input the result at one point in a series of operations to another point; the method allows a system to monitor its actions and make necessary corrections.



feedback, 1.

feedback amplifier 1. An amplifier whose performance (especially frequency response) is modified by means of positive, negative or both positive and negative feedback. 2. An amplifier placed in the feedback path of another circuit to increase the amplitude of feedback.

feedback attenuation 1. In an operational-amplifier circuit, the attenuation in the voltage from output to input. 2. In an audio-frequency or radio-frequency amplifier circuit, the reduction of feedback by electronic means.

feedback bridge A bridge circuit in the feedback channel of an amplifier or oscillator.

feedback capacitance 1. A capacitance through which feedback current is coupled from the output to the input of a circuit or system. 2. The interelectrode capacitance of a vacuum tube.

feedback control 1. The variable component (potentiometer or variable capacitor) used to adjust the level of feedback current or voltage. 2. The control of circuit performance by means of feedback.

feedback cutter A device used for the purpose of cutting grooves in phonograph disks. Feedback is used to provide a flat frequency response.

feedback factor For a feedback amplifier, the quantity $1 - bA$, where A is the open-loop gain of the amplifier and b is the FEEDBACK RATIO.

EXHIBIT "C"

"TUNABLE RC NULL NETWORKS" By Ralph Glasgal

October 1969 issue of EEE

PGS. 70-74

TUNABLE RC NULL NETWORKS

by Ralph Glasgal

□ *Some types of RC notch filters (for example, the twin-T) are deservedly popular, whereas other types have been almost completely neglected by circuit designers.*

Author Glasgal takes a second look at some of these less-popular circuits and shows how (unlike the twin-T) a few of them have the advantage that they're easy to adjust. □

The advent of linear ICs has awakened new interest in filter circuits that don't need inductors and which can therefore be more easily integrated. More and more circuit designers are now turning to null-producing RC networks as a substitute for LC networks in such circuits as active filters[1] and oscillators.

But, to achieve the versatility of LC circuits, the RC networks must be readily adjustable. Capacitors can't be easily adjusted over a wide range — either mechanically or electronically. For these reasons, we are forced to vary the resistive components of RC networks, just as we usually vary the inductors in conventional LC circuits.

In this article, we will look at the schematics and transfer functions of all the easily-tunable six-element RC networks that have a common ground for input and output (i.e. three-terminal networks).

Some of these networks can be adjusted by changing only a single resistor. These networks are well suited for electronic frequency control.

Other networks can be adjusted by changing the ratio of two adjacent resistors, using a potentiometer. These circuits are better suited for servo or mechanical-control applications.

Eight-element ladder

Let's look first at the eight-element ladder network. An understanding of the theory[2] and properties of this network will help us to understand the properties of the six-element networks that are related to it.

The eight-element network is shown in Fig. 1. Its properties can be explained qualitatively, without resorting to mathematical equations. For simplicity, we will assume that the emitter followers have infinite input impedance and zero output impedance.

Phase shifts, in the two halves of the network, are in opposite directions. If all the R's and all the C's are equal, the phase difference between voltage e_a and e_b is always 180 degrees regardless of the frequency.

But, as the frequency varies, the amplitudes of e_a and e_b change. One increases proportionately while the other decreases. The two are only equal when the absolute phase shifts of e_a and e_b are each 90 degrees.

Since the phase difference between e_a and e_b is always 180 degrees, and since $e_a + e_b$ is always constant, we can always find a point on the potentiometer where the two voltages cancel, whatever the frequency.

Conversely, we can adjust the potentiometer setting to determine the null frequency. If we set the numerator of the transfer function equal to zero, we can derive an equation relating the null frequency to the potentiometer setting.

Though this network offers a wide range of frequency adjustment with a single potentiometer, it has several disadvantages.

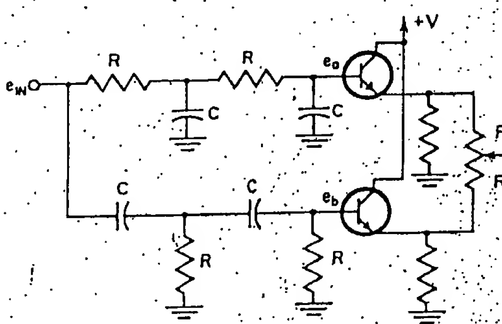
One disadvantage is its complexity. It consists of eight RC elements plus an additional potentiometer. The emitter followers, however, are not absolutely essential.

Another disadvantage is the inherent insertion loss of at least 6 dB on both sides of the notch region. We can see (from the transfer equation) that, with the potentiometer at the mid setting, $e_{out}/e_{in} = 0.5$. For any setting of the potentiometer other than the middle, attenuation is not symmetrical about the null frequency.

Yet another problem, related to the problem of asymmetry, is the nature of the phase response. Though the phase of the output signal

Author: Mr. Glasgal is now a consultant in New York City. When he wrote this article he was a Design Engineer with Siemens AG in Munich, West Germany.

Simple filter circuits that can be tuned by adjusting a single resistor or potentiometer.



$$y = \frac{R_1}{R_1 + R_2} \qquad x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{1 - y - yx^2}{1 + 3jx - x^2}$$

$$f_{null} = \frac{1}{2\pi RC}\sqrt{\frac{1-y}{y}}$$

$$\phi_{null} = \pm \tan^{-1}\frac{3\left(\frac{1-y}{y}\right)^{1/2}}{1 - \left(\frac{1-y}{y}\right)}$$

Fig. 1A. Tunable eight-element ladder network.

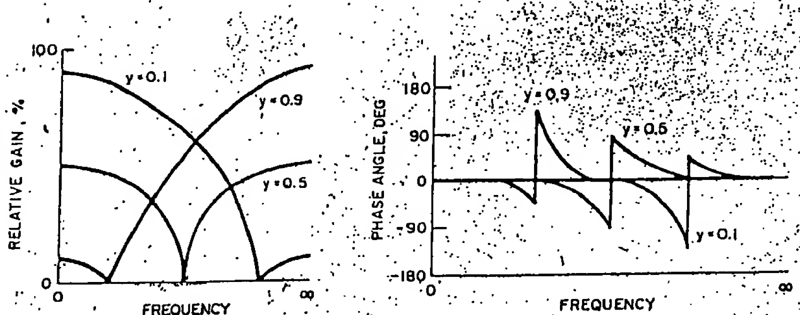
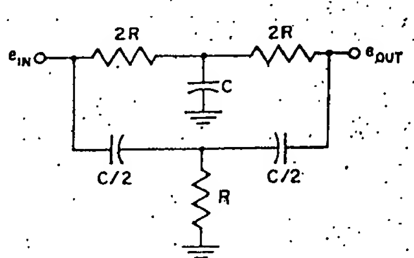


Fig. 1B. Transfer characteristics of the eight-element ladder.

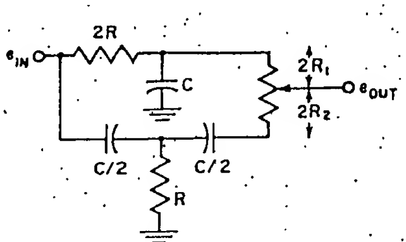


$$x = 2\pi fCR$$

$$\frac{e_{out}}{e_{in}} = \frac{1 - x^2}{1 + 4jx - x^2}$$

$$f_{null} = \frac{1}{2\pi CR}$$

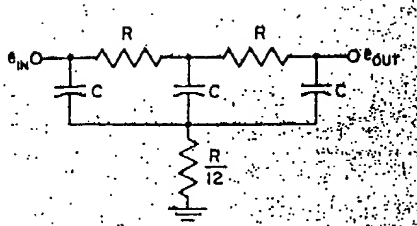
Fig. 2A. Basic twin-T null network is derived from the ladder network.



$$y = \frac{R_2}{R_1 + R_2}$$

$$\frac{e_{out}}{e_{in}} = \frac{1 - x^2 + jyx - yx^2}{1 + 4jx - x^2}$$

Fig. 2B. Twin-T cannot be tuned in the same way as the ladder network. A potentiometer, connected as shown, doesn't provide useful adjustment.

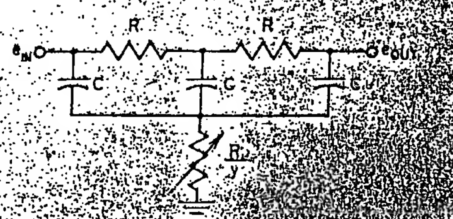


$$x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{12 + 3jx - 4x^2 - jx^3}{12 + 39jx - 16x^2 - jx^3}$$

$$f_{null} = \frac{\sqrt{3}}{2\pi RC}$$

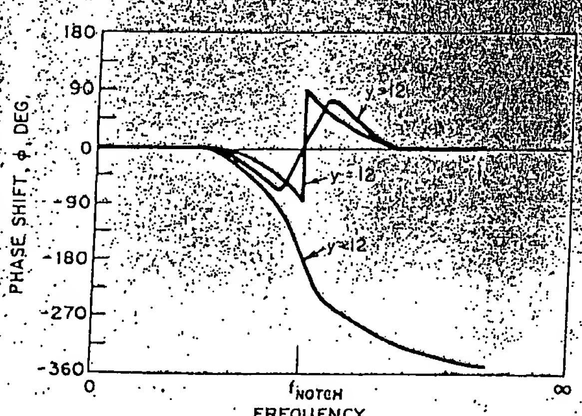
Fig. 3A. Basic isolated-integrator network.



$$\frac{e_{out}}{e_{in}} = \frac{y + 3jx - 4x^2 - jx^3}{y + 3(1+y)jx - (4+y)x^2 - jx^3}$$

$$f_{notch} \cong \frac{1}{2\pi RC}\left(\sqrt{\frac{73 + 24y \text{ [illegible]}}{\text{[illegible]}}}\right)$$

Fig. 3B. Tunable isolated integrator can be adjusted by varying a single resistor. Note that one end of the resistor is grounded.



$$\phi = \tan^{-1}\frac{3x - x^3}{y - 4x^2} - \tan^{-1}\frac{3x(1+y) - x^3}{y - (4+y)x^2}$$

Fig. 3C. Phase response of tunable isolated-integrator for various potentiometer settings.

always shifts instantaneously by 180 degrees, as frequency crosses the null frequency, the exact form of the phase response depends on the potentiometer setting.

Typical phase-response curves are shown in Fig. 1B. When $y = 0.5$, the relative phase angle (between output and input) changes abruptly from +90 to −90 degrees. But, for other settings of the potentiometer (i.e. for other values of y), the phase could jump from +135 to −45 degrees, or from +45 to −135 degrees, as shown. In fact, the phase could jump between any two phase angles that are 180 degrees apart and which lie within the region +179 to −179 degrees.

For the networks considered here, we will find in general that the instantaneous 180-degree phase change occurs only in those cases where the notch attenuation is truly infinite. For those filters with finite notch attenuation, the phase curve in the region of the notch frequency will not have infinite slope — neither will it span a full 180 degrees.

Twin-T null network

The well-known twin-T network is shown in Fig. 2A. We can see at a glance that it closely resembles the ladder network of Fig. 1. The twin-T circuit saves one resistor and one capacitor because, in each half of the circuit, the opposite T section replaces the fourth element of the ladder chain.

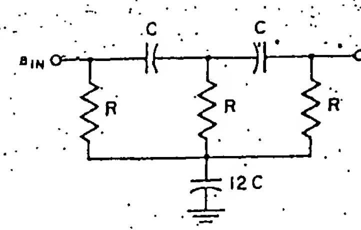
Based on our experience with the circuit of Fig. 1, we might suppose that we could tune the twin-T with a potentiometer as shown in Fig. 2B. But, in practice, this proves to be a very poor technique. The notch frequency shifts only a small amount with large changes in potentiometer setting. Also, the circuit gives large residual notch voltages and has asymmetric attenuation and phase characteristics.

Fortunately there are four other null-generating six-element networks that we can choose from. Later we will see that three of these networks are more easily adjustable than the twin-T.

Schematics of the three adjustable networks are shown in Figs. 3, 4 and 5, along with their design equations. Fig. 6 shows two other configurations that one might be tempted to use but which provide no simple tuning method.

For want of better names for the various six-element networks, let's follow the example of Van Emden[3] and call the circuit of Fig. 3 an "isolated integrator." Then we can refer to the other networks as the "isolated differentiator" (Fig. 4), the "bridged differentiator" (Fig. 5), and the "bridged integrator" (Fig. 6B).

When we start to look at the tunability of these networks, we can quickly dispose of the bridged integrator. With the circuit of Fig. 6B, as with the twin-T, it is impossible to vary the resistors and still retain a good notch. Also, there is no potentiometer setting that gives a symmetrical response curve.



$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 3x^2 - 12jx^3}{1 + 16jx - 39x^2 - 12jx^3}$$

$$f_{null} = \frac{1}{2\pi RC\sqrt{3}} \qquad x = 2\pi fCR$$

Fig. 4A. Basic isolated-differentiator network.

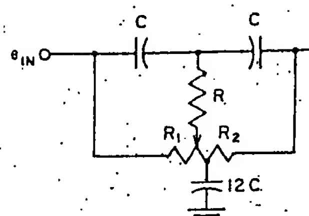
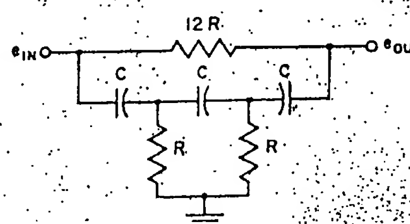


Fig. 4B. With a potentiometer connected as shown, notch frequency of the isolated differentiator can only be adjusted over a range of a few percent.

$$y = \frac{R_1}{R_1 + R_2}$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 2x^2 - 4(y - y^2)x^2 - 48j(y - y^2)x^3}{1 + 4jx + 24yjx - 2x^2 - 100yx^2 - 52y^2x^2 - 48(y - y^2)jx^3}$$

$$f_{notch} = \frac{1}{2\pi RC}\left(\frac{1}{4 + 8y - 8y^2} + \frac{1}{24(y - y^2)}\right)^{1/2}$$



$$x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 3x^2 - 12jx^3}{1 + 16jx - 39x^2 - 12jx^3}$$

$$f_{null} = \frac{1}{2\pi RC\sqrt{3}}$$

Fig. 5A. Basic bridged-differentiator network.

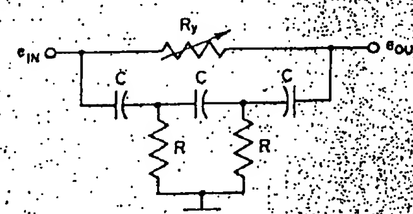
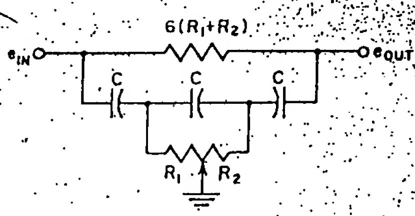


Fig. 5B, Resistor-tuned bridged differentiator. A disadvantage of this circuit is that neither end of the tuning resistor can be grounded.

$$\frac{e_{out}}{e_{in}} = \frac{1 + 4jx - 3x^2 - yjx^3}{1 + (4 + y)jx - 3(1 + y)x^2 - yjx^3}$$

$$f_{notch} \approx \frac{1}{2\pi RC}\left(\frac{8}{3y} - \frac{3}{y^2} + \frac{1}{y}\sqrt{\frac{9}{y^2} + \frac{34}{9} - \frac{16}{y}}\right)^{1/2}$$

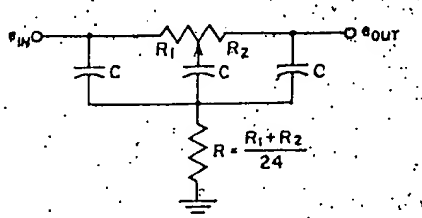
$$y = \frac{R_1}{R_1 + R_2} \qquad x = 2\pi f(R_1 + R_2)C$$



$$\frac{e_{out}}{e_{in}} = \frac{1 + 2jx - 3(y - y^2)x^2 - 6(y - y^2)jx^3}{1 + 16yx - 3(2 - y^2 + 3y)x^2 - 6(y - y^2)jx^3}$$

$$f_{null} = \frac{1}{2\pi C\sqrt{3R_1 R_2}}$$

Fig. 5C. Potentiometer-tuned bridged differentiator. Regardless of the potentiometer setting, this network always gives infinite attenuation at the null.

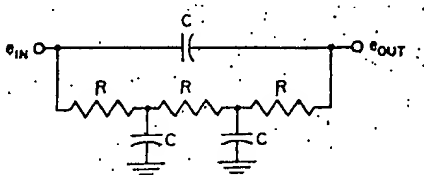


$$y = \frac{R_1}{R_1 + R_2} \qquad x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{1 + 3jx - 48x^2 - (24)^2(y - y^2)jx^3}{1 + 27jx + 24yjx - 48x^2 - (24)^2(y - y^2)x^2 - (24)^2(y - y^2)jx^3}$$

$$f_{null} = \frac{1}{\sqrt{48}\,2\pi RC}$$

Fig. 6A. One might be tempted to try this method of adjusting the isolated integrator. But the potentiometer has absolutely no effect on the null frequency.



$$x = 2\pi fRC$$

$$\frac{e_{out}}{e_{in}} = \frac{12 + 3jx - 4x^2 - jx^3}{12 + 39xj - 16x^2 - jx^3}$$

$$f_{null} = \frac{\sqrt{3}}{2\pi RC}$$

Fig. 6B. Basic bridged-integrator network is shown here for completeness only. This network offers no convenient tuning method.

Isolated integrator

One special advantage of the isolated integrator, shown in Fig. 3, is that its notch frequency is easily adjusted in both directions by means of a single variable resistor. So, the circuit can be adjusted remotely and electronically, using devices such as photoresistors, thermistors and nonlinear diodes.

Sensitivity of the frequency adjustment is quite high. A resistance change of 10 percent gives a notch-frequency variation of about 3.5 percent. Attenuation is always symmetrical on both sides of the notch — provided source and load impedance are negligible.

But the circuit of Fig. 3B does have several disadvantages. An infinite-attenuation notch can only be achieved with one value of R/y. If the resistance is adjusted too far from this optimum value, the notch becomes too shallow for most applications.

Another disadvantage of the isolated integrator is that phase response depends on the value of R/y. For low values of R/y, the phase angle is always negative as shown in Fig. 3C. But, when R/y is large, the phase angle does reverse from a negative angle through zero to a positive angle.

One other possible disadvantage is that the values of the capacitive elements are larger than in an equivalent twin-T network. From the equations we find that the capacitors are larger by a factor of $\sqrt{3}$. This makes the isolated integrator less suitable for fabrication in IC form.

Another possible configuration for the isolated integrator is shown in Fig. 6A. This arrangement has little or no practical value and is shown here merely to complete the list of possibilities. Rotating the potentiometer produces absolutely no change in the notch frequency.

Isolated differentiator

One network that can be tuned by a potentiometer is shown in Fig. 4B. This circuit is a variation of the isolated differentiator shown in Fig. 4A.

Unfortunately, with this circuit, frequency adjustment is very insensitive. The first 20-percent shift of the potentiometer in either direction from its mid point produces a frequency shift of less than 2 percent.

Also, the depth of the null is adversely affected by variations in potentiometer setting, as was the case with the isolated integrator circuit. But, in those applications where we need very fine tuning (say a few Hz per kHz), this network could be useful.

Bridged differentiator

The bridged differentiator[4], shown in Fig. 5A, can be adjusted in two ways. It can either be tuned with a variable resistor as shown in Fig. 5B, or with a potentiometer as in Fig. 5C.

With single-resistor adjustment (Fig. 5B), the network behaves much like the isolated integrator, in that the depth of the notch decreases as the resistor is varied from its nominal value R/y. But this type of bridged differentiator has the added disadvantage that neither end of the tuning resistor is at ground potential. So this circuit is probably not as widely useful as the isolated integrator.

But, when we examine the behavior of the potentiometer-tuned version (Fig. 5C), we get a pleasant surprise.

With this network, the depth of the notch remains infinite while the notch frequency can be varied over a wide range. Sensitivity increases parabolically with y as the notch frequency is increased unidirectionally from a minimum value.

The phase response is stable, too. Relative phase hovers about 90 degrees, in the vicinity of the null, and changes only slightly with the setting of the potentiometer.

One disadvantage is that the attenuation curve is not symmetrical, except when the potentiometer is in its mid position. Even with a low-source impedance, the filter behaves more and more like a low-pass filter as the frequency increases. This is the same problem that arose with the eight-element ladder network.

Which network?

The principal advantages and disadvantages of each of the networks are summarized in the table. Probably the most useful network, for control by a single variable resistor is the isolated integrator. The fact that one leg of the variable resistor can be grounded makes this network especially attractive. The resistor can easily be replaced by various types of transducer elements for automatic control.

On the other hand, where complete rejection at the null frequency is imperative, and where mechanical adjustment is feasible, then the bridged differentiator is probably the best choice. EEE

COMPARISON OF RC NULL NETWORKS

Network type	Tunable with single variable resistors?	Tunable with single pot?	Is variable element grounded?	Is null rejection infinite?	Control sensitivity	Is attenuation symmetrical?
Eight-element ladder	No	Yes	No	Yes	High	No
Twin T	No	No	—	—	—	—
Bridged integrator	No	No	—	—	—	—
Isolated integrator	Yes	No	Yes	No	High	Yes
Isolated differentiator	No	Yes	No	No	Low	Yes
Bridged differentiator	Yes		No	No	High	Yes
Bridged differentiator		Yes	Yes	Yes	Med.	No

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The Illustrated Dictionary of Electronics

Seventh Edition

Stan Gibilisco
Editor-in-Chief

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or displayed, would appear in a row or column, but not both (as in a matrix)].

character subset A classification of characters within a set.

Charactron A cathode-ray readout tube that displays letters, numbers, and symbols on its screen. More commonly called a *monitor*.

charcoal tube In a system for producing a high vacuum, a trap containing activated charcoal, which is heated to dull red, then cooled by liquid air to absorb gases.

charge **1.** A quantity of electricity associated with a space, particle, or body. **2.** To electrify a space, particle, or body (i.e., to give an electric charge). **3.** To store electricity, as in a storage battery or capacitor. Compare DISCHARGE.

charge carrier **1.** An ELECTRON whose movement constitutes a flow of electric current. **2.** An electron deficiency (HOLE) whose movement constitutes a flow of electric current. **3.** Any particle, such as a charged atom (ION), PROTON, ALPHA PARTICLE, or BETA PARTICLE, whose movement constitutes a flow of electric current.

charge-coupled device Abbreviation, CCD. A form of analog-to-digital converter that generates a digital signal output representing an analog image input. The transfer of stored charges provides the method of operation. Used in machine vision systems and in numerous scientific applications.

charge density The degree of charge or current-carrier concentration in a region.

charged particle **1.** See CHARGE CARRIER. **2.** See ION.

charged voltage **1.** The voltage across a fully charged capacitor. **2.** The terminal voltage of a fully charged storage cell.

charge holding See CHARGE RETENTION.

charge of electron The negative electric charge carried by a single electron. Approximately equal to 1.602×10^{-19} coulombs.

charger **1.** See BATTERY CHARGER. **2.** Any device or circuit that charges a capacitor.

charge retention **1.** The holding of an electric charge by a cell or battery when no current is being drawn from it. **2.** A measure of the ability of a cell or battery to maintain an electric charge when no current is drawn from it. Often specified in terms of *shelf life*. **3.** The holding of a charge by a capacitor.

charge-storage tube A cathode-ray tube that holds a display of information on its screen until the operator removes it by pressing an erase button.

charge-to-mass The ratio of the electric charge to the mass of a subatomic particle.

charge-to-mass ratio of electron The ratio of the charge (e) of the electron to the mass (m_e) of the electron, in coulombs per kilogram (C/kg). For an electron at rest, e/m_e is approximately equal to 1.602×10^{-19} C divided by 9.11×10^{-31} kg = 1.76×10^{11} C/kg.

charge transfer **1.** The switching of an electric charge from one capacitor to another. **2.** The capture of an electron by a positive ion from a neutral atom of the same kind, resulting in the ion becoming a neutral atom, and the previously neutral atom becoming a positive ion.

charge transfer device A semiconductor in which an electric charge is moved from location to location. Applications include delay lines, video signal processing, and signal storage.

charging **1.** The process of storing electrical energy in a capacitor. **2.** The process of storing electrochemical energy in a storage cell or battery.

charging current **1.** The current flowing into a capacitor. **2.** The current flowing into a previously discharged storage cell.

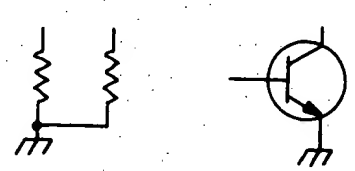
charging rate **1.** The rate at which charging current flows into a storage cell or battery, expressed in amperes or milliamperes. For most cells and batteries, the rate is greatest initially, when the cell or battery is depleted or nearly depleted; the rate decreases as the cell or battery becomes charged. **2.** The instantaneous rate at which charging current flows into a capacitor or capacitance-resistance circuit, expressed in amperes, milliamperes, or microamperes.

charged voltage **1.** The voltage across a fully charged capacitor. **2.** The terminal voltage of a fully charged storage cell.

Charlie Phonetic alphabet code word for the letter C.

chassis A (usually metal) foundation on which components are mounted and wired.

chassis ground A ground connection made to the metal chassis on which the components of a circuit are mounted. When several ground connections are made to a single point on the chassis, a COMMON GROUND results.



chassis ground

chatter **1.** A rapidly repetitive signal, caused by interruption or variation of a current (usually interference). **2.** Extraneous vibration, as of the armature in a relay.

chatter time The interval between the instant that contacts close (for example, in a relay) and the instant at which chatter ends.

cheater cord An extension cord used to conduct power to a piece of equipment (especially a television receiver) by temporarily bypassing the safety switch or interlock. Use of such a cord

of wire. The current flows through the coil, the resulting magnetic field magnetizing the vanes. Because the magnetic poles of the vanes are identical, they repel each other; the movable vane is deflected (against the torque of returning springs) over an arc proportional to the current, carrying the pointer over the scale.

irradiance The amount of radiant flux impinging on a unit surface area; it is generally specified in watts per square meter (W/m^2).

irradiation **1.** Exposure of a device to radioactivity or X rays. **2.** The total radiant power density that is incident upon a receiving surface.

irrational number A number that cannot be expressed as the quotient of two integers. Its decimal expansion is nonterminating and nonrepeating.

irregularity **1.** The condition of being nonuniform, or rapidly fluctuating, rather than constant. **2.** A departure from normal operating conditions. **3.** Nonuniformity in a surface. **4.** Nonuniform distribution of matter. **5.** Nonuniform distribution of data.

IR viewer A device that allows observation of images at infrared wavelengths. See SNIPERSCOPE and SNOOPERSCOPE.

I_s **1.** Symbol for source current in a field-effect transistor. **2.** Symbol for *screen current* in a vacuum tube.

ISDN Abbreviation for INTEGRATED SERVICES DIGITAL NETWORK.

ISCAN Abbreviation of *inertialess steerable communications antenna.*

I-scan A radar display in which the target is shown as a complete circle, whose radius is proportional to the distance to the target.

I-signal With the Z-signal, one of the two signals that modulates the chrominance subcarrier in color television. The I-signal results from mixing a B-Y signal (with -0.27 polarity) and an R-Y signal (with +0.74 polarity).

Isinglass Thinly laminated mica.

ISO Abbreviation for *International Standards Organization.*

ISO 9660 A standard format for producing CD-ROM (COMPACT DISK READ-ONLY MEMORY) mass storage media for use with computers. It is a part of the YELLOW BOOK scheme.

isobar **1.** An atom whose nucleus has the same weight as that of another atom but differs in atomic number. **2.** On a weather map, a line connecting points of equal pressure. Also see BAR, 1.

isochromal phenomena **1.** Effects occurring at regular time intervals. **2.** Effects of equal duration.

isochromatic Also *orthochromatic*. **1.** The quality of having or producing natural visible-light hues. **2.** Color sensitivity excluding a response to red.

isochronal See ISOCHRONE.

isochrone On a map, a line connecting points of constant time difference in radio-signal reception. It is useful in radiolocation and radionavigation.

isochronous Having identical resonant frequencies or wavelengths.

isoclinic line See ACLINIC LINE.

isodose Pertaining to points receiving identical dosage of radiation.

isodynamic line On a map of the geomagnetic field (the earth's magnetic field), a line connecting points of equal flux density.

isoelectric Having a potential difference of zero.

isoelectronic Having the same number of electrons.

isogonal **1.** See ISOGONIC LINE. **2.** Having uniform magnetic declination at all points.

isogonic line On a map of the geomagnetic field (the earth's magnetic field), a line connecting points of equal magnetic declination.

isolantite An insulating ceramic. Dielectric constant, 6.1.

isolated **1.** Electrically insulated. **2.** Separated in such a way that interaction does not take place.

isolated input **1.** An ungrounded input. **2.** An input circuit with a blocking capacitor to prevent the passage of direct current.

isolated location In a computer, a storage location that is hardware-protected from being addressed by a user's program.

isolating amplifier See BUFFER, 1.

isolating capacitor A series capacitor inserted in a circuit to pass an alternating-current signal while blocking direct current. Also called a BLOCKING CAPACITOR.

isolating diode A diode used (because of its unidirectional conduction) to pass signals in one direction, but block them in the other direction.

isolating resistor A high-value resistor connected in series with the input circuit of a voltmeter or oscilloscope to protect the instrument from stray pickup. In most voltmeters, this resistor is built into the probe.

isolating transformer A power transformer, usually having a 1:1 turns ratio, for isolating equipment from direct connection to the power line.

isolation The arrangement or operation of a circuit so that signals in one portion are not transferred to (nor affect) another portion.

isolation amplifier See ISOLATING AMPLIFIER.

isolation capacitor See ISOLATING CAPACITOR.

isolation diode **1.** In an integrated circuit, a reverse-biased diode that is formed in the substrate to prevent cross-coupling and grounds. **2.** See ISOLATING DIODE.

isolation resistor See ISOLATING RESISTOR.

isolation transformer See ISOLATING TRANSFORMER.

isolator See OPTOELECTRONIC COUPLER.

isolith A form of monolithic integrated circuit, in which the semiconductor is removed in certain places for the purpose of isolating different parts of the circuit.

isomagnetic Having equal magnetic intensity.

isomer A material that has the same atomic number or chemical formula as some other substance, but, because of a difference in the

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on November 8, 2002

Attorney: Sanders N. Hillis, Atty. Reg. No. 45,712

PATENT
Case No. 11336/108 (P00042US)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	Group Art Unit: 2816
Gerald R. STANLEY	Examiner: T. Cunningham
Serial No.: 09/748,609	
Filed: December 26, 2000	
For: ACTIVE ISOLATED-INTEGRATOR LOW-PASS FILTER WITH ATTENUATION POLES	

OFFICE ACTION RESPONSE AND AMENDMENT

BOX NON-FEE AMENDMENT
The Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

In response to the Office Action mailed August 9, 2002, please enter the following amendments and consider the following remarks.

In the Specification:

Please add the following new paragraph immediately following paragraph 20 in the BRIEF DESCRIPTION OF DRAWINGS SECTION.

-- Figure 6 is a schematic view of another pulse width modulation amplifier with a feedback filter in which the present invention could be utilized. --

Please add the following new paragraph immediately following paragraph 46 in the

DESCRIPTION OF THE PRESENT INVENTION.

-- As illustrated in Figure 6, the present invention also provides a power amplifier system 40 for driving a load 45. The power amplifier system 40 includes an input terminal for receiving a signal from a signal generator, an output terminal connected to the load 45, a pulse width modulation circuit 42 creating ripple spectra, an error amplifier and modulator 43 connected to an input of the pulse width modulation circuit 42, a demodulation filter 47 connected to an output of the pulse width modulation circuit 42, and a feedback control loop coupled to the pulse width modulation circuit 42 and including an active low-pass filter having a feedback demodulation filter 44 and an isolated integrator frequency-rejecting network. In one embodiment, the isolated-integrator frequency-rejecting network is an isolated-integrator band-reject filter. --

In the Claims:

Please amend claim 3, as follows.

3. (Amended) The system of Claim 1, wherein the low-pass filter circuit includes a Sallen & Key filter.

REMARKS

Claims 1-6 and 9-21 remain pending in the present application. Applicant thanks the Examiner for the allowance of claim 6. Consideration of pending claims 1-5 and 9-21 and allowance of these claims is respectfully requested in view of the following comments.

Claim Rejections pursuant to 35 U.S.C. §112, first and second paragraphs

Claims 9-10 were rejected pursuant to 35 U.S.C. §112, first and second paragraphs. The Examiner has deemed the connection between the output of the demodulation filter and the feedback control loop as critical or essential to the practice of the invention. Applicant respectfully refers the Examiner to paragraph 11 on page 3 in which a power amplifier system is described that includes a feedback control loop having a feedback demodulation filter. Those skilled in the art would recognize that a circuit with a feedback control loop that includes the feedback demodulation filter as disclosed by claim 9 and described by paragraph 11 would allow operation of the power amplifier system, and is therefore enabled by the specification. Applicant has added a new paragraph in the detailed description that is similar to paragraph 11 on page 3. Based on the power amplifier system described in paragraph 11, Applicant has added existing element numbers in the new paragraph and a corresponding new proposed drawing as FIGURE 6. Applicant has submitted herewith a proposed new drawing to the Official Draftsperson.

Applicant respectfully request approval of the addition of new FIGURE 6 and the new paragraph to the application. A marked up version of paragraph 11 is included as an attached VERSION WITH MARKINGS TO SHOW CHANGES MADE to indicate the differences between the new paragraph and paragraph 11. No new matter has been added by the addition of the new paragraph and FIGURE 6. Since the specification and drawings now even more clearly enable the power amplifier disclosed in claims 9 and 10, Applicant respectfully requests the

removal of the rejection of claims 9 and 10 pursuant to 35 U.S.C. §112, first and second paragraphs.

Claim Rejections pursuant to 35 U.S.C. §112, second paragraph

Claims 3 and 19 were rejected pursuant to 35 U.S.C. §112, second paragraph as being indefinite. The Examiner has indicated that claims 3 and 19 are indefinite since the low-pass filter circuit is not a Sallen & Key filter. Applicant has amended claim 3 to indicate that low-pass filter circuit includes a Sallen & Key filter. Claim 19, however, already discloses that the low-pass filter circuit includes a Sallen & Key filter. The term "includes" does not indicate that the low-pass filter is a Sallen & Key filter, only that the low-pass filter comprises a Sallen & Key filter. The term "includes" is synonymous with the term "comprises." Hewlett-Packard Co. v. Repeat-O-Type Stencil Manufacturing Corp., Inc., 123 F.3d 1445, 1451 (Fed. Cir. 1997). Accordingly, Applicant respectfully requests the removal of the rejection of claims 3 and 19 pursuant to 35 U.S.C. §112, second paragraph.

Claim Rejections pursuant to 35 U.S.C. §102(b)

Claims 1, 2, 4, 5, 13-18, 20 and 21 were rejected pursuant to 35 U.S.C. §102(b) as being anticipated by Cavigelli (U.S. Patent No. 5,635,871 hereinafter referred to as "Cavigelli"). Applicant respectfully disagrees for at least the following reasons.

Claim 1 discloses an active low-pass filter system that includes a low-pass filter circuit and an isolated-integrator band-reject filter. The low-pass filter circuit includes a resistive forward signal flow branch. The isolated-integrator band-reject filter is imbedded within the low pass filter circuit and forms part of the resistive forward signal flow branch. Claim 13 similarly discloses an active low-pass filter system that includes a low-pass filter circuit having an input terminal and an output terminal. Incorporated into the low-pass filter circuit between the input and output terminal is an isolated-integrator band-reject filter.

Cavigelli teaches, in Fig. 1 and 12a a low pass filter with three amplifying stages 7, 13 and 19 cascaded together. In Fig. 12a, in addition to the three cascaded amplifying stages 7, 13 and 19 a cascaded notch filter 202 is also taught. The Examiner has postulated that the cascaded notch filter 202 is equivalent to the isolated integrator band-reject filter disclosed in claims 1 and 13. As defined in Exhibit A, notch filters are a broad class of filters which are frequency rejection circuits, such as a band-suppression filter for producing a notch. Stan Gibilisco, The Illustrated Dictionary of Electronics, p. 474-475 (7th ed., McGraw-Hill, 1997). (see also in Exhibit A, Lawrence P. Huelsman, Chap. XIII Filter Characteristics, Section 65 General Characteristics of Filters, p. 2156 - 2159 (Wai-Kai Chen, The Circuits and Filters Handbook, CRC press, 1995)). Exhibit B includes excerpts from a treatise entitled Electronic Filter Design Handbook, Arthur B. Williams, p. 6-19 through 6-39 (McGraw-Hill 1981), and Active Filter Design Handbook, George S. Moschytz and Peter Horn p. (John Wiley, 1981) to illustrate some of the wide variety of different filters within the class described as notch filters.

In Cavigelli, the notch filter 202 is described as a filter with a notch frequency substantially above the operating frequency that is capable of reducing high frequency noise. (Col. 8 lines 63-67 and Col. 9 lines 1-6) Cavigelli, however, does not teach suggest or disclose that the notch filter 202 is an isolated integrator band-reject filter as disclosed in claims 1 and 13. In fact, Cavigelli fails to disclose any details about the notch filter 202. In Fig. 12a, the notch filter 202 is illustrated as an empty box which clearly does not teach, suggest or disclose anything with regard to the circuit configuration of the notch filter 202. Further, neither the notch filter 202 or any of the amplifying stages 7, 13 and 19 of Cavagelli disclose a tuning resistor as disclosed in claim 2; a resistive forward signal flow branch as disclosed in claim 14; a first resistor and a second resistor with the isolated integrator band-reject filter connected therebetween as disclosed by claim 16; a resistive value of zero as disclosed by claim 17; or at least three capacitors and at least two resistors of equal value as disclosed by claim 18. In fact,

VERSION WITH MARKINGS TO SHOW CHANGES MADE

Please add the following new paragraph immediately following paragraph 46 in the DESCRIPTION OF THE PRESENT INVENTION:

-- As illustrated in Figure 6, t[T]he present invention also provides a power amplifier system 40 for driving a load 45. The power amplifier system 40 includes an input terminal for receiving a signal from a signal generator, an output terminal connected to the load 45, a pulse width modulation circuit 42 creating ripple spectra, an error amplifier and modulator 43 connected to an input of the pulse width modulation circuit 42, a demodulation filter 47 connected to an output of the pulse width modulation circuit 42, and a feedback control loop coupled to the pulse width modulation circuit 42 and including an active low-pass filter having a feedback demodulation filter 44 and an isolated integrator frequency-rejecting network. In one embodiment, the isolated-integrator frequency-rejecting network is an isolated-integrator band-reject filter. --

Please amend Claim 3 as follows:

3. (Amended) The system of Claim 1, wherein the low-pass filter circuit [is]includes a Sallen & Key filter.

none of the cited prior art references teach, suggest or disclose the isolated integrator band-reject filter disclosed in claims 1 and 13, or any of the elements disclosed by claims 2, 14, 16, 17 or 18.

Accordingly, for at least the foregoing reasons, Applicant respectfully requests the Examiner to remove the rejection pursuant to 35 U.S.C. §102(b) of independent claims 1 and 13 and dependent claims 2, 14, 17 and 18. Alternatively, since dependent claims 2-5 and 14-22 depend from respective independent claims 1 and 13, removal of the 35 U.S.C. §102(b) rejection of these dependent claims is respectfully requested.

Applicant believes that claims 1-6 and 9-21 are allowable in their present form and that this application is in condition for allowance. Accordingly, it is respectfully requested that the Examiner so find and issue a Notice of Allowance in due course. Should the Examiner deem a telephone conference to be beneficial in expediting allowance of this application, the Examiner is invited to call the undersigned attorney at the telephone number listed below. No fees are believed to be due at this time, however, should any fees be deemed required, please charge such fees therefor to Deposit Account No. 23-1925.

Respectfully submitted,

Sanders N. Hillis
Attorney Reg. No. 45,712

Attachments: VERSION WITH MARKINGS TO SHOW CHANGES MADE pg. 11
Exhibits A (12 pages)
Exhibit B (28 pages)

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PG 1 OF 4

The Illustrated Dictionary of Electronics

Seventh Edition

Stan Gibilisco
Editor-in-Chief

McGraw-Hill

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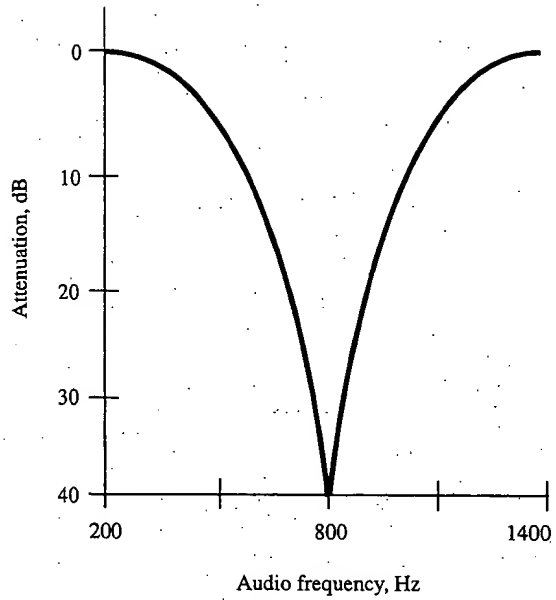
PAGE 3 OF 4

normal-distribution curve See BELL-SHAPED CURVE.
normal electrode A standard electrode used in electrode-potential measurements.
normal fault An unintended path between the hot terminal of a load and ground.
normal fault plus grounded neutral fault A combination of NORMAL FAULT and GROUNDED NEUTRAL FAULT.
normal glow discharge In a glow-discharge tube, the discharge region between the Townsend discharge and the abnormal glow in which current increases sharply, but a constant voltage drop is maintained across the tube.
normal impedance A transducer's input impedance when the load impedance is zero.
normal induction curve A saturation curve for a magnetic material. Also see BOX-SHAPED LOOP and SATURABLE REACTOR.
normalize In computer programming, to use floating-point numbers to modify the fixed-point part of a number so that it is within a desired range.
normalized admittance The quantity $1/Z_n$, where Z_n is NORMALIZED IMPEDANCE.
normalized frequency The unitless number represented by the ratio f/f_r, where f_r is a reference frequency and f is a frequency of interest. Response plots are sometimes conveniently drawn on the basis of normalized frequency, the reference (or resonant) frequency being indicated as **1**, twice the reference frequency as **2**, etc.
normalized impedance A value of impedance divided by the characteristic impedance of a waveguide.
normally closed Abbreviation, NC. Pertaining to a switch or relay whose contacts are closed when the device is at rest. Compare NORMALLY OPEN.
normally open Abbreviation, NO. Pertaining to a switch or relay whose contacts are open when the device is at rest. Compare NORMALLY CLOSED.
normal mode Pertaining to a device or system operated in its usual or most common manner.
normal mode A state of acoustic resonance in an enclosure, such as a speaker cabinet or a room.
normal-mode rejection Abbreviation, NMR. In a digital direct-current voltmeter, the level of noise on the applied voltage that will be rejected by the instrument. Compare COMMON-MODE REJECTION.
normal position In a switch or relay, the state of the contacts when the device is at rest.
normal solution A solution, such as an electrolyte, in which the amount of dissolved material is chemically equivalent to 1 gram-atomic weight of hydrogen per liter of the solution. Compare MOLAR SOLUTION.
normal state of atom The condition in which an atom is at its lowest energy level. For the hydrogen atom, for example, the state in which the electron is in the lowest-energy orbit.
normal-through A feature in an audio PATCH BAY or PATCH PANEL that connects two sockets by default. The top socket and the one immediately below it are connected, even when a patch cord is not plugged into either of them.
northern lights See AURORA.
north magnetic pole The north pole of the equivalent bar magnet constituted by the EARTH'S MAGNETIC FIELD. The north magnetic pole lies close to the geographic north pole. Compare SOUTH MAGNETIC POLE.
north pole **1.** See NORTH MAGNETIC POLE. **2.** The earth's geographic north pole. **3.** See NORTH-SEEKING POLE.
north-seeking pole Symbol, N. The so-called north pole of a magnet. When the magnet is suspended horizontally, this pole points in the direction of the earth's north magnetic pole. Compare SOUTH-SEEKING POLE.
Norton's equivalent An equivalent circuit based on NORTON'S THEOREM, replacing a Thevenin equivalent for a current-actuated device, such as a bipolar transistor. Also see THEVENIN'S THEOREM.
Norton's theorem With reference to a particular set of terminals, any network containing any number of generators and any number of constant impedances can be simplified to one constant-current generator and one impedance. The equivalent circuit will deliver to a given load the same current that would flow if the output terminals of the original circuit where short-circuited. Compare COMPENSATION THEOREM, MAXIMUM POWER TRANSFER THEOREM, RECIPROCITY THEOREM, SUPERPOSITION THEOREM, and THEVENIN'S THEOREM.
NOT In binary logic, an operation that changes high to low and vice-versa. Also see NAND CIRCUIT, NOR CIRCUIT, NOR GATE, NOT CIRCUIT, and NOT-OR CIRCUIT.
NOT-AND circuit See NAND CIRCUIT.
notation The way that numbers, quantities, or formulas are represented (e.g., *binary notation*, *Polish notation*, and *scientific notation*).
notch A dip in frequency response, typical of a band-suppression (band-elimination) filter or other frequency-rejection circuit. Compare PEAK, **3**.
notch amplifier An amplifier containing a notch filter or other arrangement that permits it to reject one frequency or a given band of frequencies while passing all higher and lower frequencies.
notch antenna An antenna with a slot in the radiating surface, for the purpose of obtaining a directional response.
notcher See NOTCH FILTER.
notcher-peaker A circuit or device that can be set to perform either as a NOTCH FILTER or PEAK FILTER.
notch filter A frequency-rejection circuit, such as a band-suppression filter, for producing a notch.



notch

notch gate In radar, a gate that determines the minimum and maximum range.

notch sweep An oscilloscope sweep that expands only a small portion (notch) of the pattern on the screen, leaving the portions on either side of the notch untouched. Thus, the first dozen or so cycles might appear at the normal sweep speed, the next two cycles expanded, and the remaining two or three at normal sweep speed.

NOT circuit A logic circuit that provides an output pulse when there is no input pulse, and vice-versa. Also called COMPLEMENTER, NEGATOR, and INVERTER.

note See BEAT NOTE.

notebook computer A portable personal computer, also called a *laptop computer.* It is about the size of a typical three-ring notebook, and generally contains a DISKETTE DRIVE, a HARD DISK, a MODEM, and attachments for peripherals, such as printers. It uses rechargeable batteries and can be operated for approximately two to six hours between battery charges.

NOT gate A digital circuit that inverts a logical condition—either from high (logic 1) to low (logic 0) or vice-versa. Also called an *inverter.*

NOT-OR circuit A logical OR CIRCUIT combined with a NOT CIRCUIT.

novelty calculator See SPECIAL-PURPOSE CALCULATOR.

November Phonetic alphabet code word for the letter N.

novice **1.** A beginner class of amateur radio license. **2.** Any beginner or inexperienced practitioner.

no-voltage release In the starting box for a shunt motor, the electromagnet that normally holds the arm in full-running position. It is connected directly across the power line to disconnect the motor in the event of power failure. When the arm is released, it falls to its off position, thereby preventing burnout that would result if the motor were left connected to the line in the full-running position when power resumed. Compare NO-FIELD RELEASE.

noys scale A scale of apparent acoustic noise, based on a linear function instead of the more common logarithmic function.

Np **1.** Symbol for NEPTUNIUM. **2.** Abbreviation of NEPER.

N_p Symbol for number of primary turns in a transformer.

n-phase system A polyphase system having n phases.

npin transistor A junction transistor having an intrinsic layer between a p-type base and an n-type collector. The emitter is a second n-type layer on the other side of the base.

N plant See NUCLEAR POWER PLANT.

n-plus-one address instruction A computer program instruction containing two addresses, one of which specifies the location of an upcoming instruction to be executed.

NPM Symbol for *counts per minute.*

npnp device A semiconductor switching device having three junctions. Examples: FOUR-LAYER DIODE, and SILICON-CONTROLLED RECTIFIER. Also called *pnpn device.*

npn transistor A bipolar transistor in which the emitter and collector layers are n-type semiconductor material, and the base layer is p-type semiconductor material. Compare PNP TRANSISTOR.

NPO Abbreviation of NEGATIVE POSITIVE ZERO.

NPO capacitor A fixed capacitor exhibiting temperature-compensating ability over a wide temperature range, in which the coefficient has negative, positive, and zero values.

NPS Symbol for *counts per second.*

N radiation X rays emitted as a result of an electron becoming an N electron.

NRD Abbreviation of NEGATIVE-RESISTANCE DIODE.

N region See N LAYER.

NRZ Abbreviation of NONRETURN TO ZERO.

N_s Symbol for number of secondary turns in a transformer.

ns Abbreviation of NANOSECOND.

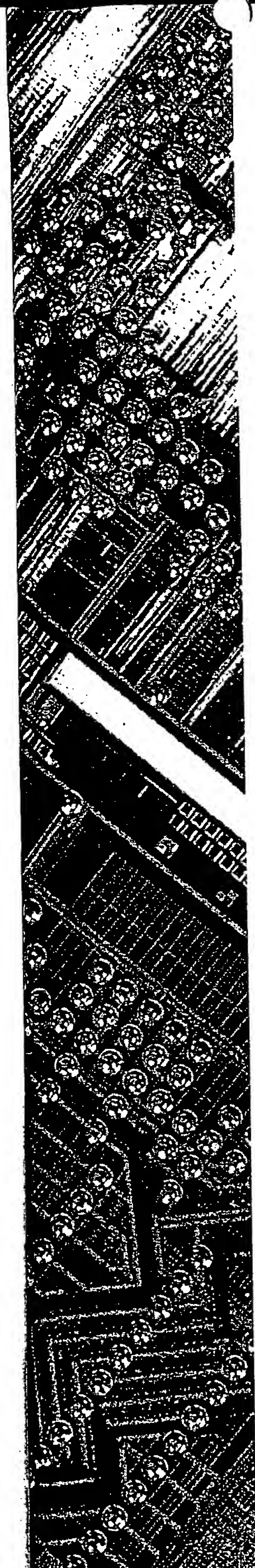
N scan See N DISPLAY.

N scope Colloquialism for a radar set using an N DISPLAY.

nsec Alternate abbreviation of NANOSECOND.

Ns/m² Newton-seconds per meter squared, the unit of dynamic viscosity.

n-space A coordinate system in n variables. It is generally of mathematical interest. The coordinates are written $(x_1, x_2, x_3, \ldots, x_n)$ and are called *ordered n-tuples.*



THE CIRCUITS and FILTERS HANDBOOK

Editor-in-Chief

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Chicago, Illinois

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PG 2 OF 8

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XIII

Filter Characteristics

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University of Arizona

65

General Characteristics of Filters

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University of Victoria, Canada

65.1 Introduction

An electrical filter is a system that can be used to modify, reshape, or manipulate the frequency spectrum of an electrical signal according to some prescribed requirements. For example, a filter may be used to amplify or attenuate a range of frequency components, reject or isolate one specific frequency component, and so on. The applications of electrical filters are numerous, for example,

- to eliminate signal contamination such as noise in communication systems
- to separate relevant from irrelevant frequency components
- to detect signals in radios and TV's
- to demodulate signals
- to bandlimit signals before sampling
- to convert sampled signals into continuous-time signals
- to improve the quality of audio equipment, e.g., loudspeakers
- in time-division to frequency-division muliplex systems

0-8493-8341-2/95/$0.00 + $.50

where zeros and poles occur in complex conjugate pairs, i.e., $z_2 = z_1^*$ and $p_2 = p_1^*$. Such a circuit is commonly referred to as a *biquad*.

After some manipulation, the transfer function in (65.26) can be expressed as

$$H_{BQ}(s) = K\frac{s^2 + (2\,\mathrm{Re}\,z_1)s + (\mathrm{Re}\,z_1)^2 + (\mathrm{Im}\,z_1)^2}{s^2 + (2\,\mathrm{Re}\,p_1)s + (\mathrm{Re}\,p_1)^2 + (\mathrm{Im}\,p_1)^2}$$
$$= K\frac{s^2 + (\omega_z/Q_z)s + \omega_z^2}{s^2 + (\omega_p/Q_p)s + \omega_p^2}$$

where $K = a_2$, ω_z, and ω_p are the zero and pole frequencies, and Q_z and Q_p are the zero and pole *quality factors* (or Q factors for short), respectively. The formulas for the various parameters are as follows:

$$\omega_z = \sqrt{(\mathrm{Re}\,z_1)^2 + (\mathrm{Im}\,z_1)^2}$$
$$\omega_p = \sqrt{(\mathrm{Re}\;p_1)^2 + (\mathrm{Im}\,p_1)^2}$$
$$Q_z = \frac{\omega_z}{2\;\mathrm{Re}\;z_1}$$
$$Q_p = \frac{\omega_p}{2\;\mathrm{Re}\;p_1}$$

The zero and pole frequencies are approximately equal to the frequencies of minimum gain and maximum gain, respectively. The zero and pole Q factors have to do with the selectivity of the filter. A high zero Q factor results in a deep notch in the amplitude response, whereas a high pole Q factor results in a very peaky amplitude response.

The dc gain and the gain as $\omega \to \infty$ in dB are given by

$$M_0 = 20\log|H_{BQ}(0)| = 20\log\left(K\,\frac{\omega_z^2}{\omega_p^2}\right)$$

and

$$M_\infty = 20\log|H_{BQ}(j\infty)| = 20\log K$$

respectively.

Types of Basic Filter Sections

Depending on the values of the transfer function coefficients, five basic types of filter sections can be identified, namely, low-pass, high-pass, bandpass, notch (sometimes referred to as bandreject), and allpass. These sections can serve as building blocks for the design of filters that can satisfy arbitrary specifications. They are actually sufficient for the design of all the standard types of filters, namely, Butterworth, Chebyshev, inverse-Chebyshev, and elliptic filters.

Low-pass Section

In a *low-pass* section, we have $a_2 = a_1 = 0$ and $a_0 = K\omega_p^2$. Hence the transfer function assumes the form

$$H_{LP}(s) = \frac{a_0}{s^2 + b_1 s + b_0} = \frac{K\omega_p^2}{s^2 + (\omega_p/Q_p)s + \omega_p^2}$$

[See Fig. 65.11(a).]

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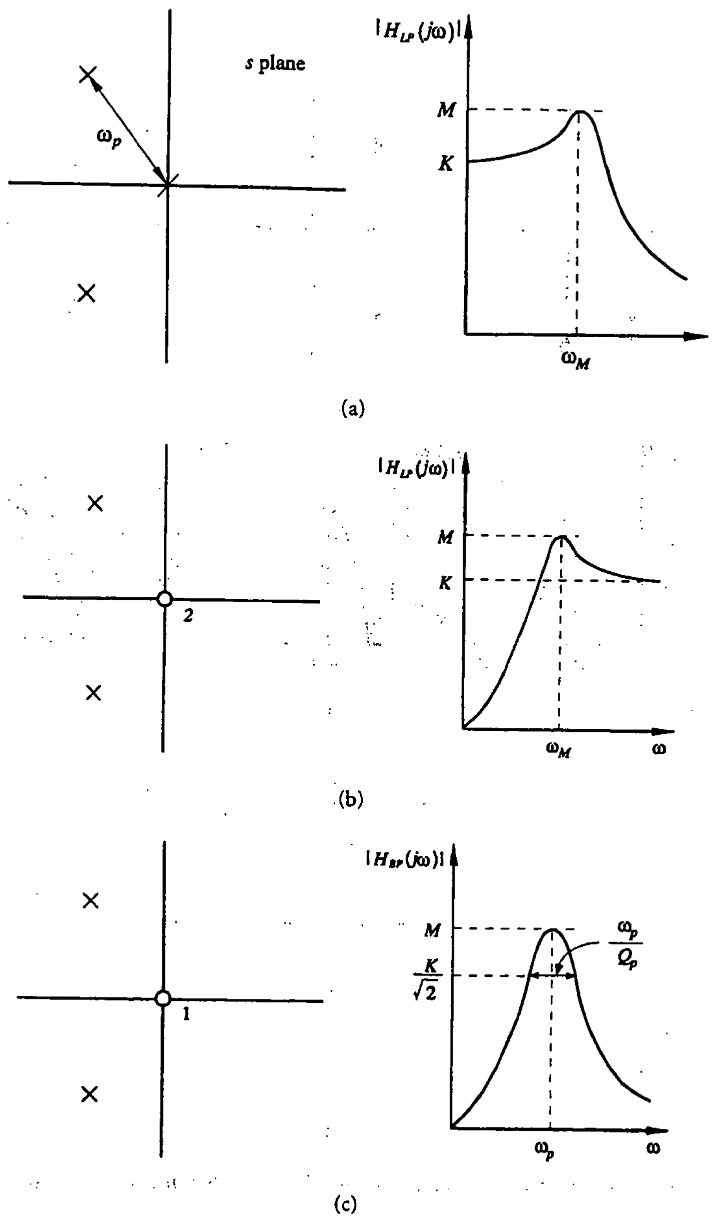

FIGURE 65.11 Basic second-order filter sections: (a) low-pass, (b) high-pass, (c) bandpass.

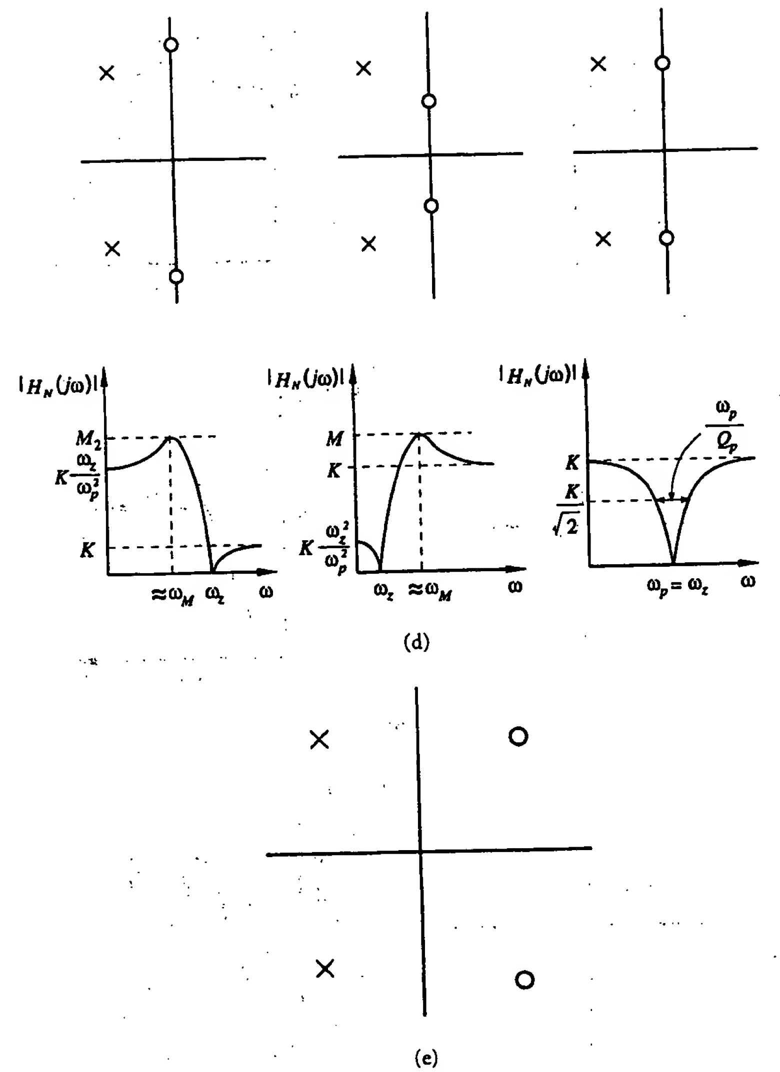

FIGURE 65.11 (Continued) Basic second-order filter sections: (d) notch, (e) allpass.

Re

High-Pass Section

In a *high-pass* section, we have $a_2 = K$ and $a_1 = a_0 = 0$. Hence the transfer function assumes the form

$$H_{\mathrm{HP}}(s) = \frac{a_2 s^2}{s^2 + b_1 s + b_0} = \frac{Ks^2}{s^2 + (\omega_p/Q_p)s + \omega_p^2}$$

[See Fig. 65.11(b).]

Bandpass Section

In a *bandpass* section, we have $a_1 = K\omega_p/Q_p$ and $a_2 = a_0 = 0$. Hence the transfer function assumes the form

$$H_{\mathrm{BP}}(s) = \frac{a_1 s}{s^2 + b_1 s + b_0} = \frac{K(\omega_p/Q_p)s}{s^2 + (\omega_p/Q_p)s + \omega_p^2}$$

[See Fig. 65.11(c).]

Notch Section

In a *notch* section, we have $a_2 = K$, $a_1 = 0$, and $a_0 = K\omega_z^2$. Hence the transfer function assumes the form

$$H_{\mathrm{N}}(s) = \frac{a_2 s^2 + a_0}{s^2 + b_1 s + b_0} = \frac{K(s^2 + \omega_z^2)}{s^2 + (\omega_p/Q_p)s + \omega_p^2}$$

[See Fig. 65.11(d).]

Allpass Section

In an *allpass* section, we have $a_2 = K$, $a_1 = -K\omega_p/Q_p$, and $a_0 = K\omega_p^2$. Hence the transfer function assumes the form

$$H_{\mathrm{AP}}(s) = \frac{a_2 s^2 + a_1 s + a_0}{s^2 + b_1 s + b_0} = \frac{K[s^2 - (\omega_p/Q_p)s + \omega_p^2]}{s^2 + (\omega_p/Q_p)s + \omega_p^2}$$

[See Fig. 65.11(e).]

The design of active and switched-capacitor filters is treated in some detail in Section XV.

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ELECTRONIC FILTER DESIGN HANDBOOK

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and Children Howard, Bonnie, and Robin
Mrs. Jean Williams and Mr. and Mrs. Marcus Fuhr
for all their Love, Encouragement, and Inspiration

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A center-tapped inductor is not always available or practical. An alternate form of a bridged-T is given in figure 6-15. The parallel resonant trap design of figure 6-9 is modified by splitting the capacitor into two capacitors of twice the value, and a resistor of $\omega_0 LQ_L/4$ is introduced. The two capacitors should be closely matched.

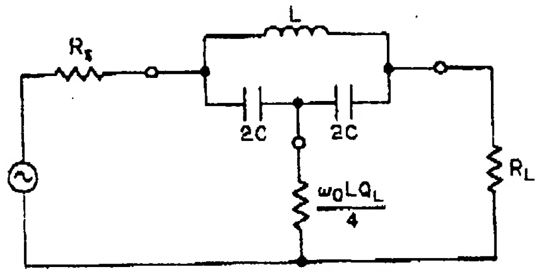


Fig. 6-15 Alternate form of bridged-T.

In conclusion, the bridged-T structure is an economical and effective means of increasing the available notch rejection of a parallel resonant trap without increasing the inductor Q. However, as a final general comment, a single null section can provide high rejection only at a single frequency or relatively narrow band of frequencies for a given 3-dB bandwidth, since $n = 1$. The stability of the circuit then becomes a significant factor. A higher-order band-reject filter design can have a wider stopband and yet maintain the same 3-dB bandwidth.

6.2 ACTIVE BAND-REJECT FILTERS

This section considers the design of active band-reject filters for both wide-band and narrow-band applications. Active null networks are covered and the popular twin-T circuit is discussed in detail.

Wide-Band Active Band-Reject Filters

Wide-band filters can be designed by first separating the specification into individual low-pass and high-pass requirements. Low-pass and high-pass filters are then independently designed and combined by paralleling the inputs and summing both outputs to form the band-reject filter.

A wide-band approach is valid when the separation between cutoffs is an octave or more for all-pole filters so that minimum interaction occurs in the stopband when the outputs are summed (see section 2.1 and figure 2-13). Elliptic-function networks will require less separation, since their characteristics are steeper.

An inverting amplifier is used for summing and can also provide gain. Filters can be combined using the configuration of figure 6-16a, where R is arbitrary and A is the desired gain. The individual filters should have a low output impedance to avoid loading by the summing resistors.

The VCVS elliptic-function low-pass and high-pass filters of sections 3.2 and 4.2 each require an RC termination on the last stage to provide the real pole. These elements can be combined with the summing resistors, resulting in the circuit of figure 6-16b. R_a and C_a correspond to the denormalized values of R_5 and C_5 for the low-pass filter of figure 3-20. The denormalized high-pass

filter real-pole values are R_b and C_b. If only one filter is of the VCVS type, the summing network of the filter having the low output impedance can be replaced by a single resistor having a value of R.

When one or both filters are of the elliptic-function type, the ultimate attenuation obtainable is determined by the filter having the lesser value of A_{min}, since the stopband output is the summation of the contributions of both filters.

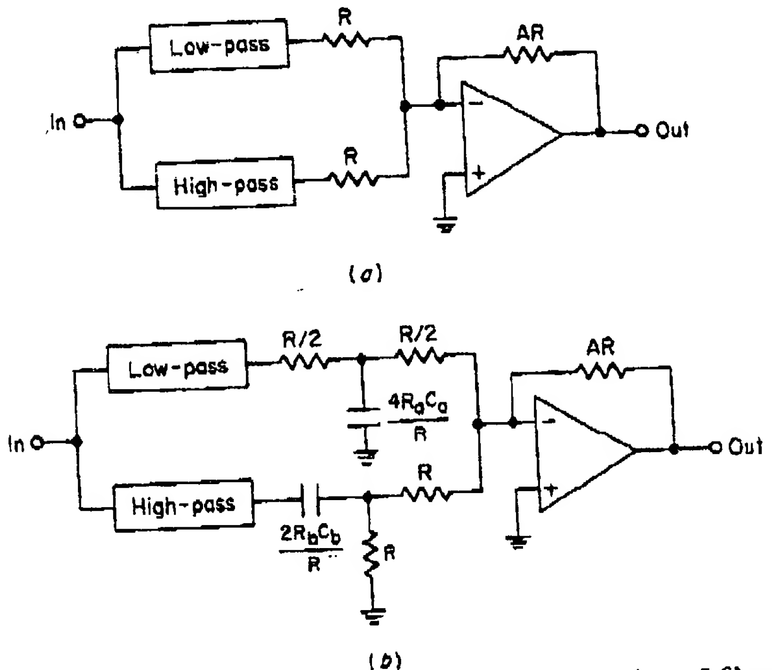


Fig. 6-16 Wide-band band-reject filters: *(a)* combining of filters having low output impedance; *(b)* combined filters requiring *RC* real poles.

Example 6-6

REQUIRED: Design an active band-reject filter having 3-dB points at 100 and 400 Hz and greater than 35 dB of attenuation between 175 and 225 Hz.

RESULT: *(a)* Since the ratio of upper cutoff to lower cutoff is well in excess of an octave, a wide-band approach can be used. First separate the specification into individual low-pass and high-pass requirements.

Low-pass:	**High-pass:**
3 dB at 100 Hz	3 dB at 400 Hz
35 dB minimum at 175 Hz	35 dB minimum at 225 Hz

(b) The low-pass and high-pass filters can now be independently designed as follows:

Low-pass filter:

Compute the steepness factor.

$$A_s = \frac{f_s}{f_c} = \frac{175\ \text{Hz}}{100\ \text{Hz}} = 1.75 \tag{2-11}$$

An $n = 5$ Chebyshev filter having a 0.5-dB ripple is chosen using figure 2-44. The normalized active low-pass filter values are given in table 12-39 and the circuit is shown in figure 6-17*a*.

To denormalize the filter, multiply all resistors by Z and divide all capacitors by $Z \times$ FSF, where Z is conveniently selected at 10^6 and the FSF is $2\pi f_c$, where f_c is 100 Hz. The denormalized low-pass filter is given in figure 6-17*b*.

High-pass filter:

Compute the steepness factor.

$$A_s = \frac{f_c}{f_s} = \frac{400 \text{ Hz}}{225 \text{ Hz}} = 1.78 \tag{2-13}$$

An $n = 5$ Chebyshev filter with a 0.5-dB ripple will also satisfy the high-pass requirement. A high-pass transformation can be performed on the normalized low-pass filter of figure 6-17*a* to obtain the circuit of figure 6-17*c*. All resistors have been replaced with capacitors and vice versa using reciprocal element values.

The normalized high-pass filter is then frequency- and impedance-scaled by multiplying all resistors by Z and dividing all capacitors by $Z \times$ FSF, where Z is chosen at 10^6 and FSF is $2\pi f_c$, using an f_c of 400 Hz. The denormalized high-pass filter is shown in figure 6-17*d* using standard 1% resistor values.

(*c*) The individual low-pass and high-pass filters can now be combined using the configuration of figure 6-16*a*. Since no gain is required, A is set equal to unity. The value of R is conveniently selected at 10 kΩ, resulting in the circuit of figure 6-17*e*.

Band-Reject Transformation of Low-Pass Poles

The wide-band approach to the design of band-reject filters using combined low-pass and high-pass networks is applicable to bandwidths of typically an octave or more. If the separation between cutoffs is insufficient, interaction in the stopband will occur, resulting in inadequate stopband rejection (see figure 2-13).

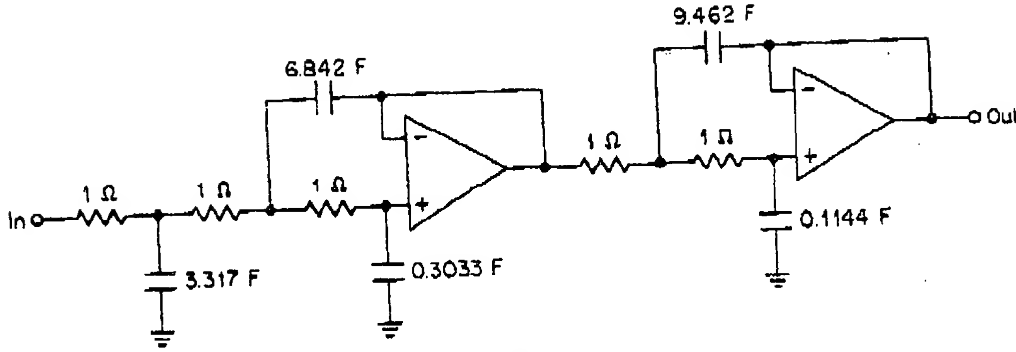
A more general approach involves normalizing the band-reject requirement and selecting a normalized low-pass filter type that meets these specifications. The corresponding normalized low-pass poles are then directly transformed to the band-reject form and realized using active sections.

A band-reject transfer function can be derived from a low-pass transfer function by substituting the frequency variable f by a new variable given by

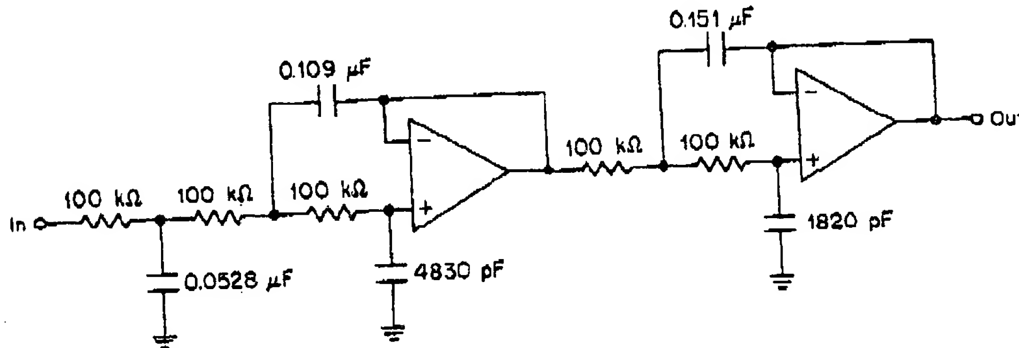
$$f_{br} = \frac{1}{f_0\left(\dfrac{f}{f_0} - \dfrac{f_0}{f}\right)} \tag{6-32}$$

This transformation combines the low-pass to high-pass and subsequent band-reject transformation discussed in section 6.1 so that a band-reject filter can be obtained directly from the low-pass transfer function.

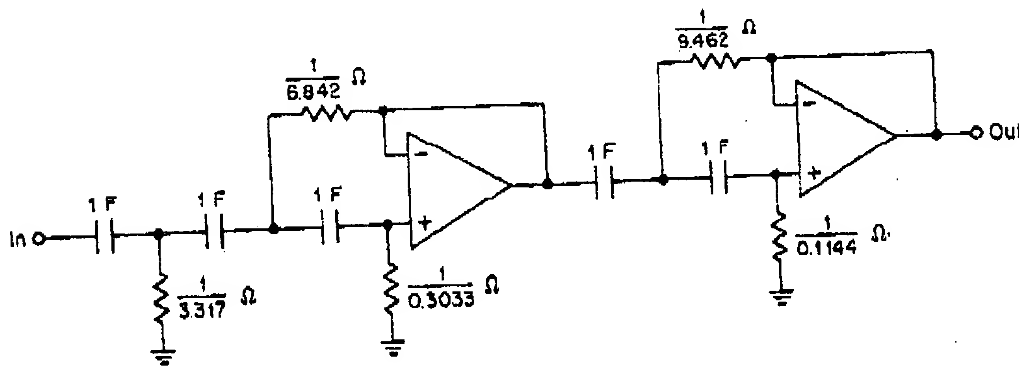
The band-reject transformation results in two pairs of complex poles and a pair of second-order imaginary zeros from each low-pass complex pole pair. A single low-pass real pole is transformed into a complex pole pair and a pair of first-order imaginary zeros. These relationships are illustrated in figure 6-18. The zeros occur at center frequency and result from the transformed low-pass zeros at infinity.


9.462 F
6.842 F
Out
1 Ω
1 Ω
1 Ω
1 Ω
1 Ω
In
3.317 F
0.3033 F
0.1144 F

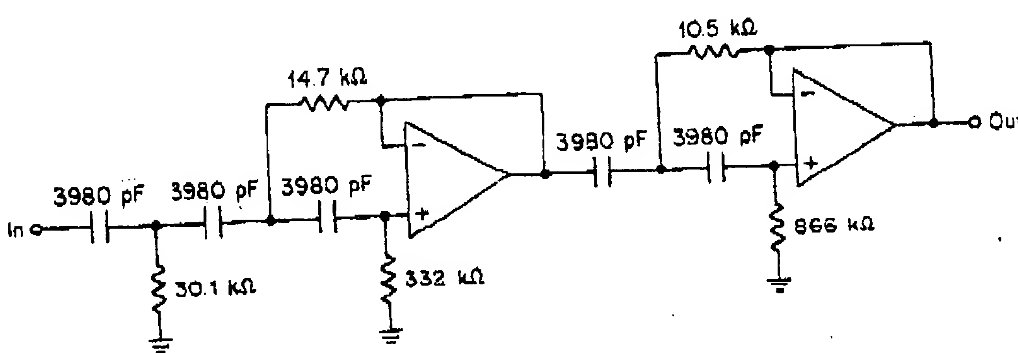
(a)


0.151 μF
0.109 μF
Out
100 kΩ
100 kΩ
100 kΩ
100 kΩ
100 kΩ
In
0.0528 μF
4830 pF
1820 pF

(b)


1/9.462 Ω
1/6.842 Ω
Out
1 F
1 F
1 F
1 F
1 F
In
1/3.317 Ω
1/0.3033 Ω
1/0.1144 Ω

(c)


10.5 kΩ
14.7 kΩ
Out
3980 pF
3980 pF
3980 pF
3980 pF
3980 pF
In
30.1 kΩ
332 kΩ
866 kΩ

(d)

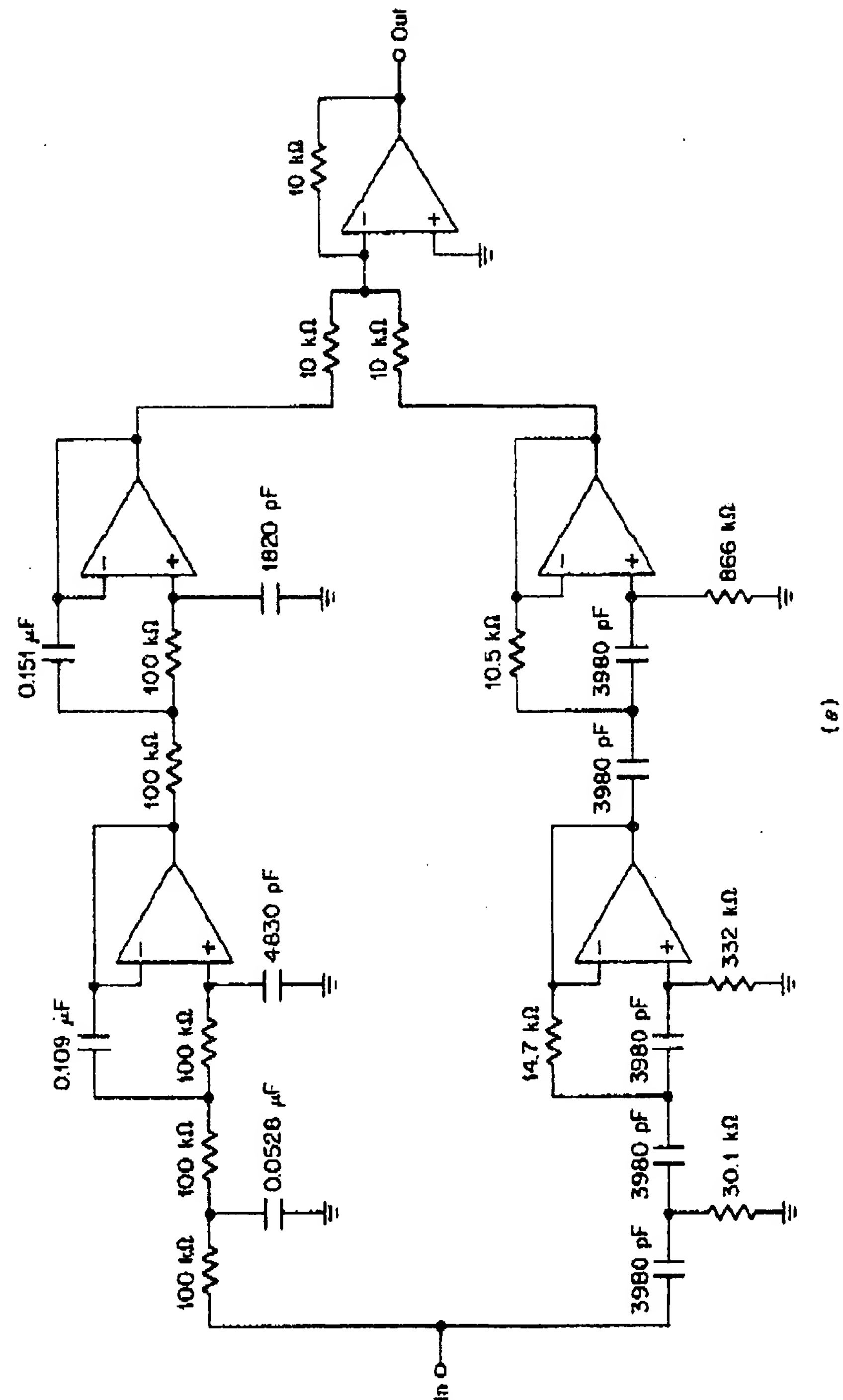


Fig. 6-17 Wide-band band-reject filter of example 6-6: *(a)* normalized low-pass filter; *(b)* denormalized low-pass filter; *(c)* transformed normalized high-pass filter; *(d)* denormalized high-pass filter; *(e)* combining filters to obtain band-reject response.

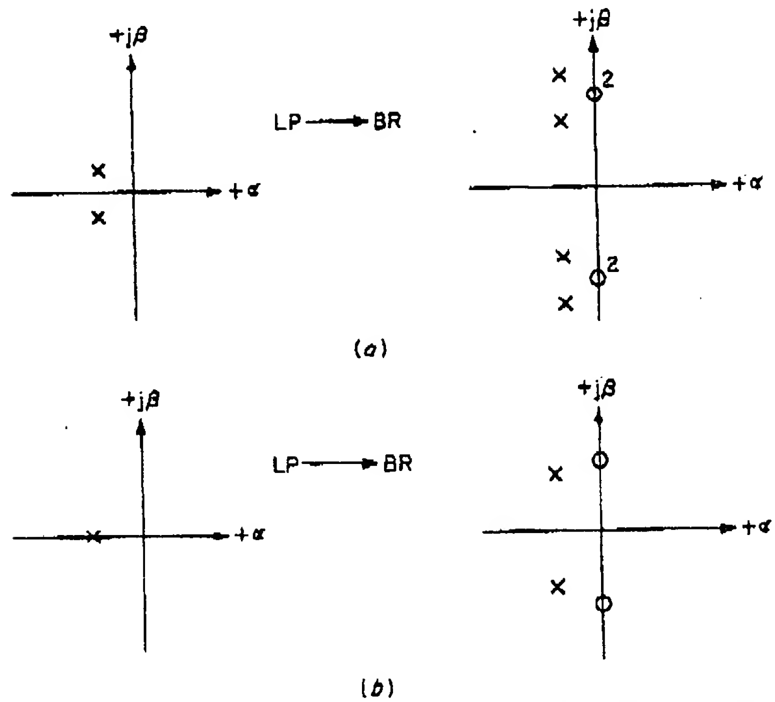


Fig. 6-18 Band-reject transformation of low-pass poles: *(a)* low-pass complex pole pair; *(b)* low-pass real pole.

The band-reject pole-zero pattern of figure 6-18*a* corresponds to two band-reject sections where each section provides a zero at center frequency and provides one of the pole pairs. The pattern of figure 6-18*b* is realized by a single band-reject section where the zero also occurs at center frequency.

To make the low-pass to band-reject transformation, first compute

$$Q_{br} = \frac{f_0}{BW} \tag{6-33}$$

where f_0 is the geometric center frequency and BW is the passband bandwidth. The transformation then proceeds as follows:

Complex Poles The tables of chapter 12 contain tabulated poles corresponding to the all-pole low-pass filter families discussed in chapter 2. Complex poles are given in the form: $-\alpha \pm j\beta$ where α is the real coordinate and β is the imaginary part. Given α, β, Q_{br}, and f_0, the following computations result in two sets of values for Q and frequency which defines two band-reject filter sections. Each section also has a zero at f_0.

$$C = \alpha^2 + \beta^2 \tag{6-34}$$

$$D = \frac{\alpha}{Q_{br}C} \tag{6-35}$$

$$E = \frac{\beta}{Q_{br}C} \tag{6-36}$$

$$F = E^2 - D^2 + 4 \tag{6-37}$$

$$G=\sqrt{\frac{F}{2}+\sqrt{\frac{F^2}{4}+D^2E^2}} \tag{6-38}$$

$$H=\frac{DE}{G} \tag{6-39}$$

$$K=\frac{1}{2}\sqrt{(D+H)^2+(E+G)^2} \tag{6-40}$$

$$Q=\frac{K}{D+H} \tag{6-41}$$

$$f_{ra}=\frac{f_0}{K} \tag{6-42}$$

$$f_{rb}=Kf_0 \tag{6-43}$$

$$f_\infty=f_0 \tag{6-44}$$

The two band-reject sections have resonant frequencies of f_{ra} and f_{rb} (in hertz) and identical Q's given by equation (6-41). In addition each section has a zero at f_0, the filter geometric center frequency.

Real Poles A normalized low-pass real pole having a real coordinate of α_0 is transformed into a single band-reject section having a Q given by

$$Q=Q_{br}\,\alpha_0 \tag{6-45}$$

The section resonant frequency is equal to f_0, and the section must also have a transmission zero at f_0.

Example 6-7

REQUIRED: Determine the pole and zero locations for a band-reject filter having the following specifications:

Center frequency of 3600 Hz
3 dB at ±150 Hz
40 dB minimum at ±30 Hz

RESULT: (a) Since the filter is narrow, the requirement can be treated directly in its arithmetically symmetrical form:

$$f_0=3600\text{ Hz}$$
$$BW_{3\text{ dB}}=300\text{ Hz}$$
$$BW_{40\text{ dB}}=60\text{ Hz}$$

The band-reject steepness factor is given by

$$A_s=\frac{\text{passband bandwidth}}{\text{stopband bandwidth}}=\frac{300\text{ Hz}}{60\text{ Hz}}=5 \tag{2-20}$$

(b) An $n=3$ Chebyshev normalized low-pass filter having a 0.1-dB ripple is selected using figure 2-42. The corresponding pole locations are found in table 12-23 and are

$-0.3500\pm j0.8695$
-0.6999

First make the preliminary computation:

$$Q_{br}=\frac{f_0}{BW_{3\text{ dB}}}=\frac{3600\text{ Hz}}{300\text{ Hz}}=12 \tag{6-33}$$

6-26 Band-Reject Filters

The low-pass to band-reject pole transformation is performed as follows:

Complex-pole transf rmation:

$\alpha = 0.3500 \qquad \beta = 0.8695$

$$C = \alpha^2 + \beta^2 = 0.878530 \qquad (6\text{-}34)$$

$$D = \frac{\alpha}{Q_{br}C} = 0.033199 \qquad (6\text{-}35)$$

$$E = \frac{\beta}{Q_{br}C} = 0.082477 \qquad (6\text{-}36)$$

$$F = E^2 - D^2 + 4 = 4.005700 \qquad (6\text{-}37)$$

$$G = \sqrt{\frac{F}{2} + \sqrt{\frac{F^2}{4} + D^2E^2}} = 2.001425 \qquad (6\text{-}38)$$

$$H = \frac{DE}{G} = 0.001368 \qquad (6\text{-}39)$$

$$K = \frac{1}{2}\sqrt{(D+H)^2 + (E+G)^2} = 1.042094 \qquad (6\text{-}40)$$

$$Q = \frac{K}{D+H} = 30.15 \qquad (6\text{-}41)$$

$$f_{ra} = \frac{f_0}{K} = 3455 \text{ Hz} \qquad (6\text{-}42)$$

$$f_{rb} = Kf_0 = 3752 \text{ Hz} \qquad (6\text{-}43)$$

$$f_\infty = f_0 = 3600 \text{ Hz} \qquad (6\text{-}44)$$

Real-pole transformation:

$$\alpha_0 = 0.6999$$

$$Q = Q_{br}\,\alpha_0 = 8.40 \qquad (6\text{-}45)$$

$$f_r = f_\infty = f_0 = 3600 \text{ Hz}$$

The block diagram is shown in figure 6-19.

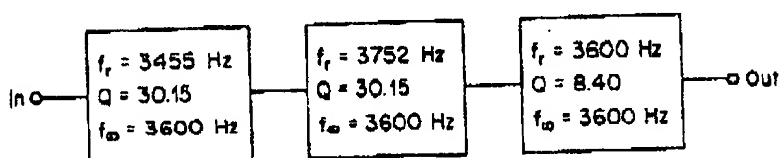


Fig. 6-19 Block diagram of example 6-7.

Narrow-Band Active Band-Reject Filters

Narrow-band active band-reject filters are designed by first transforming a set of normalized low-pass poles to the band-reject form. The band-reject poles are computed in terms of resonant frequency f_r, Q, and f_∞ using the results of section 6.2 and are then realized with active band-reject sections.

Th VCVS Band-Reje t Section Complex low-pass poles result in a set of band-reject parameters where f_r and f_∞ do not occur at the same frequency. Band-reject sections are then required that permit independent selection of f_r

and f_∞ in their design procedure. Both the VCVS and biquad circuits covered in section 5.2 under Elliptic-Function Bandpass Filters have this degree of freedom.

The VCVS realization is shown in figure 6-20. The design equations were given in section 5.2 under Elliptic-Function Bandpass Filters and are repeated

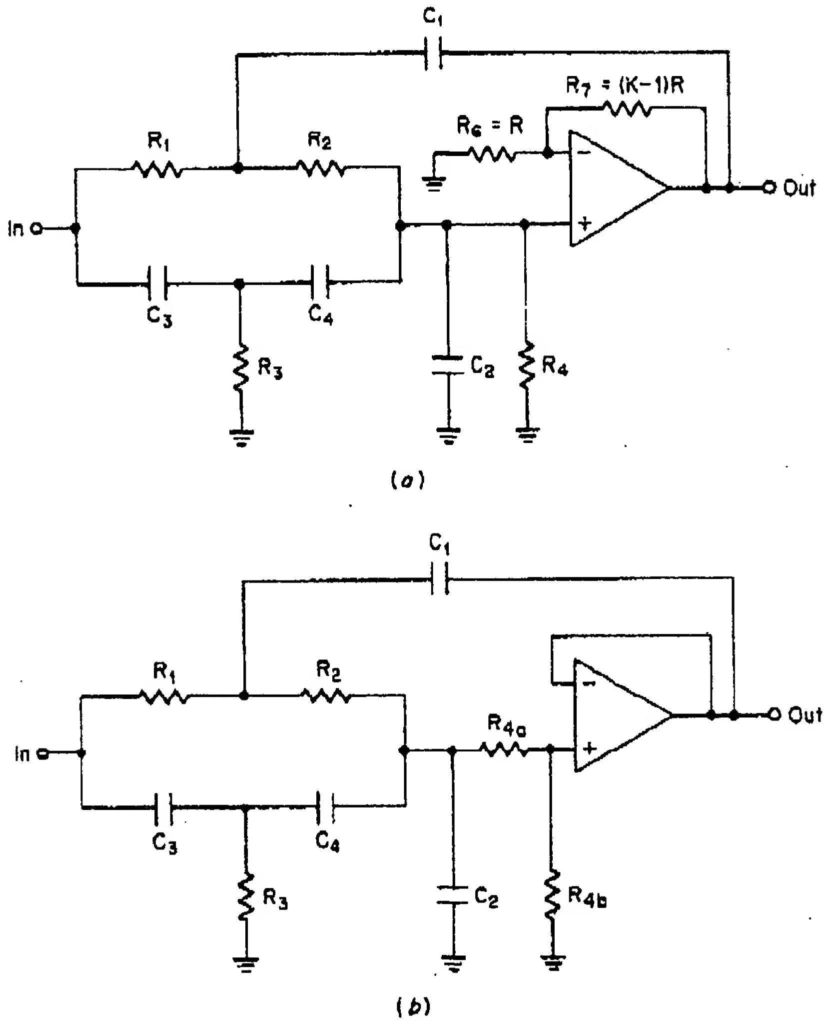


Fig. 6-20 VCVS realization for band-reject filters: *(a)* circuit for $K > 1$; *(b)* circuit for $K < 1$.

here for convenience, where f_r, Q, and f_∞ are obtained by the band-reject transformation procedure of section 6.2. The values are computed from

$$R_2 = 2R_1 \tag{6-47}$$

$$R_3 = \frac{f_\infty^2 + f_r^2}{4.5 f_r^2} R' \tag{6-48}$$

$$R_4 = 4.5 R_3 \tag{6-49}$$

$$C_1 = \frac{1.5}{2\pi f_r R_1} \tag{6-50}$$

$$C_2 = \frac{C_1}{4.5} \tag{6-51}$$

$$C_3 = \frac{f_r}{2\pi R_1 f_\infty^2} \tag{6-52}$$

$$C_4 = \frac{C_3}{2} \tag{6-53}$$

$$K = \frac{\left(2.5 - \frac{1}{Q}\right)\left(\frac{f_r^2}{f_\infty^2} + 1\right)}{1.5} \tag{6-54}$$

$$R_6 = R \tag{6-55}$$

$$R_7 = (K-1)R \tag{6-56}$$

where R' and R can be arbitrarily chosen.

The circuit of figure 6-20a is used when $K > 1$. In the cases where $K < 1$, the configuration of figure 6-20b is utilized, where

$$R_{4a} = (1-K)R_4 \tag{6-57}$$

and

$$R_{4b} = KR_4 \tag{6-58}$$

The section gain at DC is given by

$$A_{dc} = \frac{f_\infty^2}{f_r^2 + f_\infty^2} \tag{6-59}$$

The gain of the composite filter in the passband is the product of the DC gains of all the sections.

The VCVS structure has a number of undesirable characteristics. Although the circuit Q can be adjusted by making R_6 or R_7 variable when $K > 1$, the Q cannot be independently measured since the 3-dB bandwidth at the output is affected by the transmission zero. Resonant frequency f_r or the notch frequency f_∞ cannot be easily adjusted, since these parameters are determined by the interaction of a number of elements. Also the section gain is fixed by the design parameters. Another disadvantage of the circuit is that a large spread in capacitor values[1] may occur so that standard values cannot be easily used. Nevertheless the VCVS realization makes effective use of a minimum number of operational amplifiers in comparison with other implementations and is widely used. However, because of its lack of adjustment capability, its application is generally restricted to Q's below 10 and with 1% component tolerances.

The State-Variable Band-Reject Section The biquad or state-variable elliptic-function bandpass filter section discussed in section 5.2 is highly suitable for implementing band-reject transfer functions. The circuit is given in figure 6-21. By connecting resistor R_5 to either node 1 or to node 2, the notch frequency f_∞ will be located above or below the pole resonant frequency f_r.

[1] The elliptic-function configuration of the VCVS uniform capacitor structure given in section 3.2 can be used at the expense of additional sensitivity.

Section Q's of up to 200 can be obtained. The design parameters f_r, Q, and f_∞ as well as the section gain can be independently chosen, monitored, and adjusted. From the point of view of low sensitivity and maximum flexibility the biquad approach is the most desirable method of realization.

The design equations were stated in section 5.2 under Elliptic-Function Bandpass Filters and are repeated here for convenience, where f_r, Q, and f_∞ are given and the values of C, R, and R' can be arbitrarily chosen.

$$R_1 = R_4 = \frac{Q}{2\pi f_r C} \tag{6-60}$$

$$R_2 = R_3 = \frac{R_1}{Q} \tag{6-61}$$

$$R_5 = \frac{f_r^2 R}{Q|f_r^2 - f_\infty^2|} \tag{6-62}$$

for $f_\infty > f_r$:

$$R_6 = \frac{f_r^2 R}{f_\infty^2} \tag{6-63}$$

and when $f_\infty < f_r$:

$$R_6 = R \tag{6-64}$$

The value of R_6 is based on unity section gain at DC. The gain can be raised or lowered by proportionally increasing or decreasing R_6.

Resonance is adjusted by monitoring the phase shift between the section input and node 3 using a Lissajous pattern and adjusting R_3 for 180° phase shift with an input frequency of f_r.

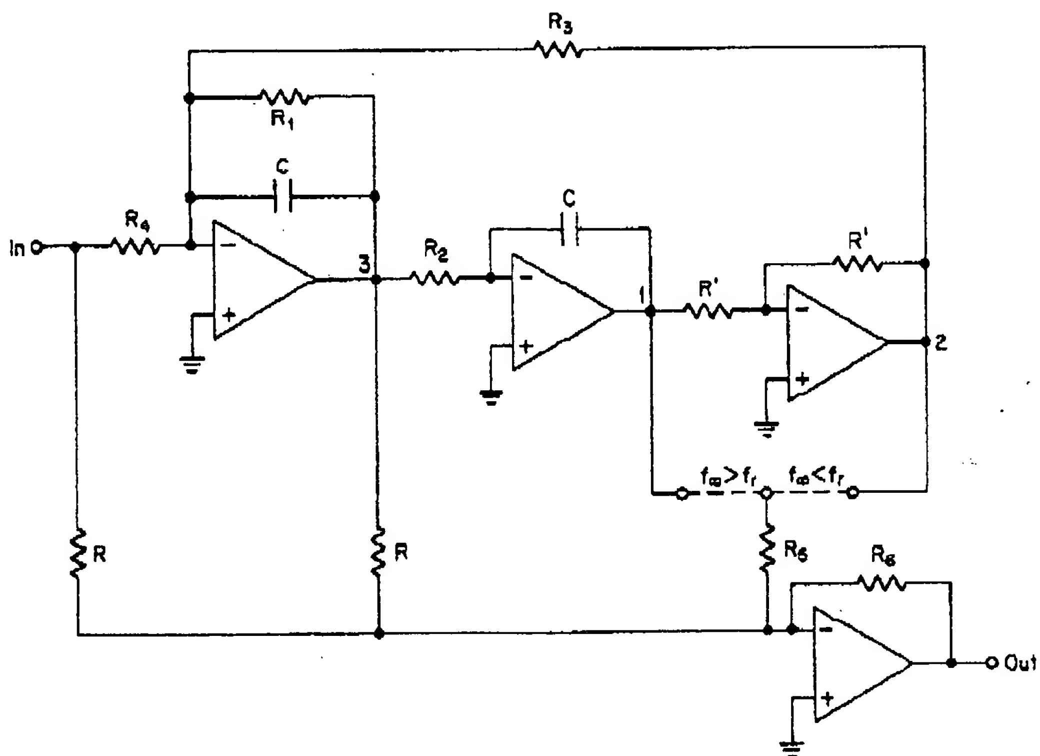


Fig. 6-21 Biquad band-reject realization.

The Q is controlled by R_1 and can be measured at node 3 in terms of section 3-dB bandwidth, or R_1 can be adjusted until unity gain occurs between the input and node 3 with f_r applied. Because of the Q enhancement effect discussed in section 5.2 under All-Pole Bandpass Configurations a Q adjustment is usually necessary.

The notch frequency is then determined by monitoring the section output for a null. Adjustment is normally not required, since tuning of f_r will usually bring in f_∞ with acceptable accuracy. If an adjustment is desired, R_5 can be made variable.

Sections for Transformed Real Poles When a real pole undergoes a band-reject transformation, the result is a single pole pair and a single set of imaginary zeros. Complex poles resulted in two sets of pole pairs and two sets of zeros. The resonant frequency f_r of the transformed real pole is exactly equal to the notch frequency f_∞; so the design flexibility of the VCVS and biquad structures is not required.

A general second-order bandpass transfer function can be expressed as

$$T(s) = \frac{\frac{\omega_r}{Q} s}{s^2 + \frac{\omega_r}{Q} s + \omega_r^2} \tag{6-65}$$

where the gain is unity at ω_r. If we realize the circuit of figure 6-22 where $T(s)$ corresponds to the above transfer function, the composite transfer function at the output is given by

$$T(s) = \frac{s^2 + \omega_r^2}{s^2 + \frac{\omega_r}{Q} s + \omega_r^2} \tag{6-66}$$

This corresponds to a band-reject transfer function having a transmission zero at f_r (i.e., $f_\infty = f_r$). The occurrence of this zero can also be explained intuitively from the structure of figure 6-22. Since $T(s)$ is unity only at f_r, both input signals to the summing amplifier will then cancel, resulting in no output signal.

These results indicate that band-reject sections for transformed real poles can be obtained by combining any of the all-pole bandpass circuits of section 5.2 in the configuration of figure 6-22. The basic design parameters are the required f_r and Q of the band-reject section which are directly used in the design equations for the bandpass circuits.

By combining these bandpass sections with summing amplifiers, the three band-reject structures of figure 6-23 can be derived. The design equations for the bandpass sections were given in section 5.2 and are repeated here where C, R, and R' can be arbitrarily chosen.

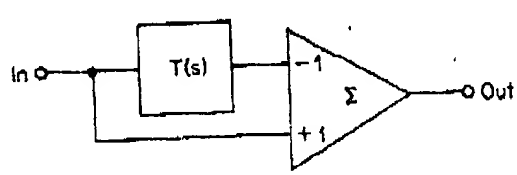


Fig. 6-22 Band-reject configuration for $f_r = f_\infty$.

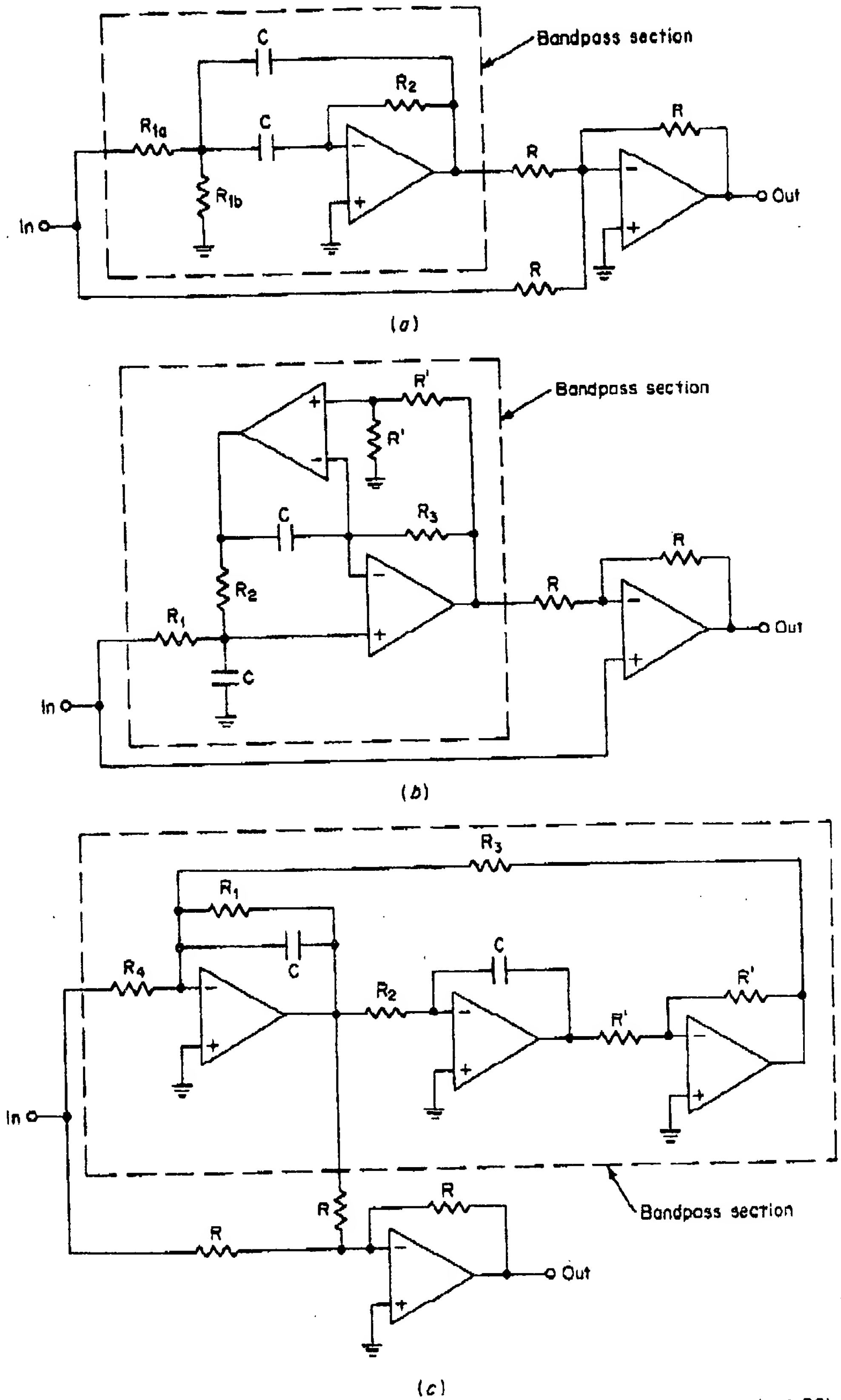


Fig. 6-23 Band-reject circuits for $f_r = f_\infty$ *(a)* MFBP band-reject section ($Q < 20$); *(b)* DABP band-reject section ($Q < 150$); *(c)* biquad band-reject section ($Q < 200$).

6-32 Band-Reject Filters

The MFBP band-reject section ($f_r = f_\infty$) is given by

$$R_2 = \frac{Q}{\pi f_r C} \tag{6-67}$$

$$R_{1a} = \frac{R_2}{2} \tag{6-68}$$

$$R_{1b} = \frac{R_{1a}}{2Q^2 - 1} \tag{6-69}$$

The DABP band-reject section ($f_r = f_\infty$) is given by

$$R_1 = \frac{Q}{2\pi f_r C} \tag{6-70}$$

$$R_2 = R_3 = \frac{R_1}{Q} \tag{6-71}$$

The biquad band-reject section ($f_r = f_\infty$) is given by

$$R_1 = R_4 = \frac{Q}{2\pi f_r C} \tag{6-72}$$

$$R_2 = R_3 = \frac{R_1}{Q} \tag{6-73}$$

These equations correspond to unity bandpass gain for the MFBP and biquad circuits so that cancellation at f_r will occur when the section input and bandpass output signals are equally combined by the summing amplifiers. Since the DABP section has a gain of 2 and has a noninverting output, the circuit of figure 6-23 *b* has been modified accordingly so that cancellation occurs.

Tuning can be accomplished by making R_{1b}, R_2, and R_3 variable in the MFBP, DABP, and biquad circuits, respectively. In addition the biquad circuit will usually require R_1 to be made adjustable to compensate for the Q-enhancement effect (see section 5.2 under All-Pole Bandpass Configurations). The circuit can be tuned by adjusting the indicated elements for either a null at f_r measured at the circuit output or for 0° or 180° phase shift at f_r observed between the input and the output of the bandpass section. If the bandpass section gain is not sufficiently close to unity for the MFBP and biquad case and 2 for the DABP circuit, the null depth may be inadequate.

Example 6-8

REQUIRED: Design an active band-reject filter from the band-reject parameters determined in example 6-7 having a gain of +6 dB.

RESULT: (*a*) The band-reject transformation in example 6-7 resulted in the following set of requirements for a three-section filter:

Section	f_r	Q	f_∞
1	3455 Hz	30.15	3600 Hz
2	3752 Hz	30.15	3600 Hz
3	3600 Hz	8.40	3600 Hz

(*b*) Two biquad circuits in tandem will be used for sections 1 and 2 followed by a DABP band-reject circuit for section 3. The value

of C is chosen at 0.01 μF and R as well as R' at 10 kΩ. Since the DABP section has a gain of 2 at DC, which satisfies the 6-dB gain requirement, both biquad sections should then have unity gain. The element values are determined as follows:

Section 1 (biquad of figure 6-21):

$f_r = 3455$ Hz $\quad Q = 30.15 \quad f_\infty = 3600$ Hz

$$R_1 = R_4 = \frac{Q}{2\pi f_r C} = \frac{30.15}{2\pi \times 3455 \times 10^{-8}} = 138.9\ \text{k}\Omega \quad (6\text{-}60)$$

$$R_2 = R_3 = \frac{R_1}{Q} = \frac{138.9 \times 10^3}{30.15} = 4610\ \Omega \quad (6\text{-}61)$$

$$R_5 = \frac{f_r^2 R}{Q|f_r^2 - f_\infty^2|} = \frac{3455^2 \times 10^4}{30.15|3455^2 - 3600^2|} = 3870\ \Omega \quad (6\text{-}62)$$

$$R_6 = \frac{f_r^2 R}{f_\infty^2} = \frac{3455^2 \times 10^4}{3600^2} = 9210\ \Omega \quad (6\text{-}63)$$

Section 2 (biquad of figure 6-21):

$f_r = 3752$ Hz $\quad Q = 30.15 \quad f_\infty = 3600$ Hz

$R_1 = R_4 = 127.9$ kΩ (6-60)
$R_2 = R_3 = 4240\ \Omega$ (6-61)
$R_5 = 4180\ \Omega$ (6-62)
$R_6 = 10$ kΩ (6-64)

Section 3 (DABP of figure 6-23):

$f_r = f_\infty = 3600$ Hz $\quad Q = 8.40$

$$R_1 = \frac{Q}{2\pi f_r C} = \frac{8.40}{2\pi \times 3600 \times 10^{-8}} = 37.1\ \text{k}\Omega \quad (6\text{-}70)$$

$$R_2 = R_3 = \frac{R_1}{Q} = \frac{37.1 \times 10^3}{8.40} = 4420\ \Omega \quad (6\text{-}71)$$

The final circuit is shown in figure 6-24 with standard 1% resistor values. The required resistors have been made variable so that the resonant frequencies can be adjusted for all sections, and in addition the Q is variable for the biquad circuits.

Active Null Networks

Active null networks are single sections used to provide attenuation at a single frequency or over a narrow band of frequencies. The most popular sections are of the twin-T form; so this circuit will be discussed in detail along with some other structures.

The Twin-T The twin-T was first discovered by H. W. Augustadt in 1934. Although this circuit is passive by nature, it is also used in many active configurations to obtain a variety of different characteristics.

The circuit of figure 6-25*a* is an *RC* bridge structure where balance or an output null occurs at 1 rad/s when all arms have an equal impedance ($0.5 - j0.5\ \Omega$). The circuit is redrawn in the form of a symmetrical lattice in figure 6-25*b* (refer to Guillemin and Stewart in references for detailed discussions of the lattice). The lattice of figure 6-25*b* can be redrawn again in the form of two parallel lattices as shown in figure 6-25*c*.

If identical series elements are present in both the series and shunt branches of a lattice, the element may be extracted and symmetrically placed outside

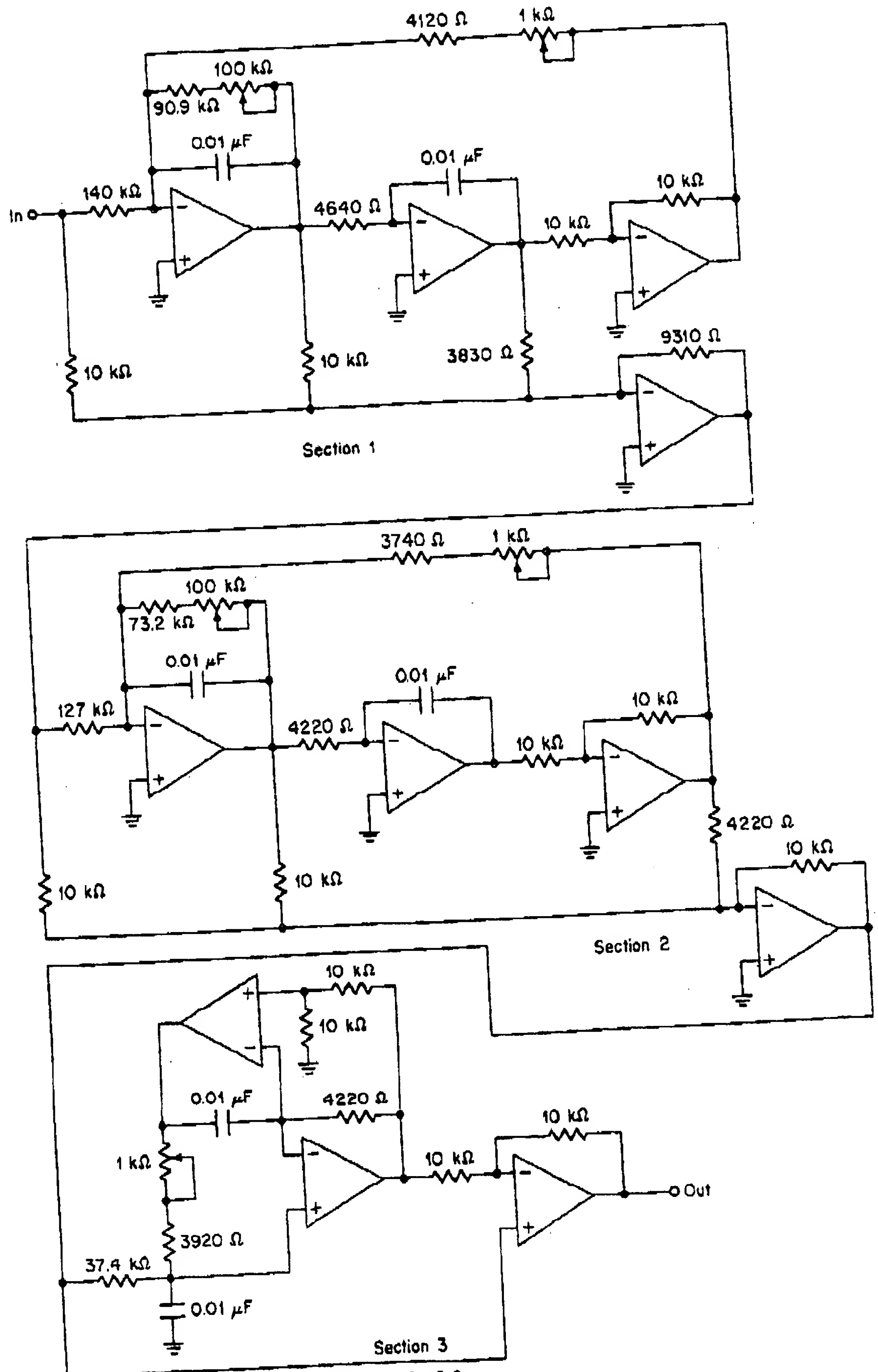


Fig. 6-24 Band-reject filter of example 6-8.

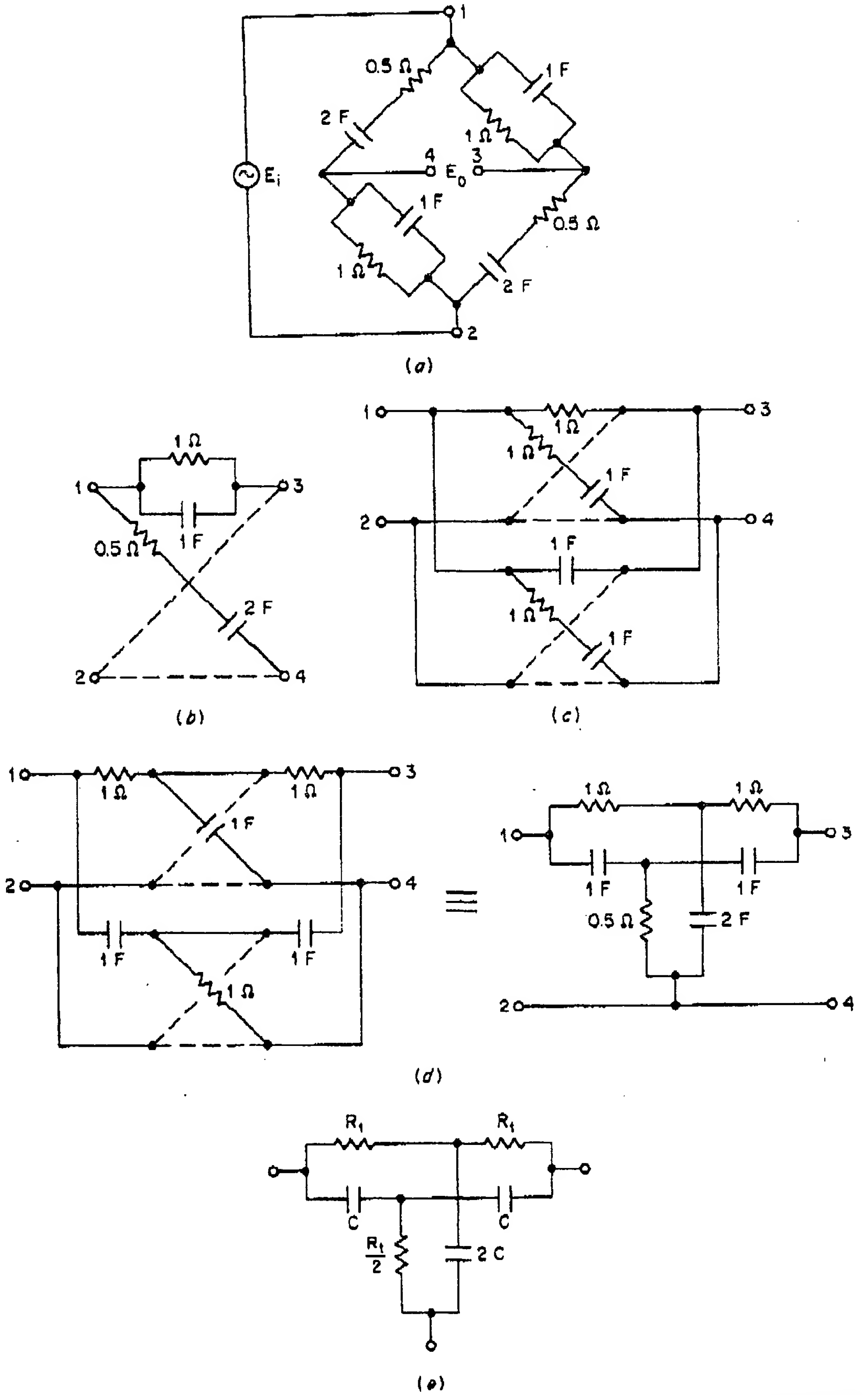


Fig. 6-25 D rivation of the twin-T: *(a) RC* bridge; *(b)* lattice circuit; *(c)* parallel lattice; *(d)* twin-T equivalent; *(e)* general form of twin-T.

the lattice structure. A 1-Ω resistor satisfies this requirement for the upper lattice and a 1-F capacitor for the lower lattice. Removal of these components to outside the lattice results in the twin-T of figure 6-25*d*.

The general form of a twin-T is shown in figure 6-25*e*. The value of R_1 is computed from

$$R_1 = \frac{1}{2\pi f_0 C} \tag{6-74}$$

where C is arbitrary. This denormalizes the circuit of figure 6-25*d* so that the null now occurs at f_0 instead of at 1 rad/s.

When a twin-T is driven from a voltage source and terminated in an infinite load,[2] the transfer function is given by

$$T(s) = \frac{s^2 + \omega_0^2}{s^2 + 4\omega_0 s + \omega_0^2} \tag{6-75}$$

If we compare this expression with the general transfer function of a second-order pole-zero section as given by equation (6-66), we can determine that a twin-T provides a notch at f_0 with a Q of ¼. The attenuation at any bandwidth can be computed by

$$A_{dB} = 10 \log \left[1 + \left(\frac{4f_0}{BW_{x\,dB}} \right)^2 \right] \tag{6-76}$$

The frequency response is shown in figure 6-26. The requirement for geometric symmetry applies.

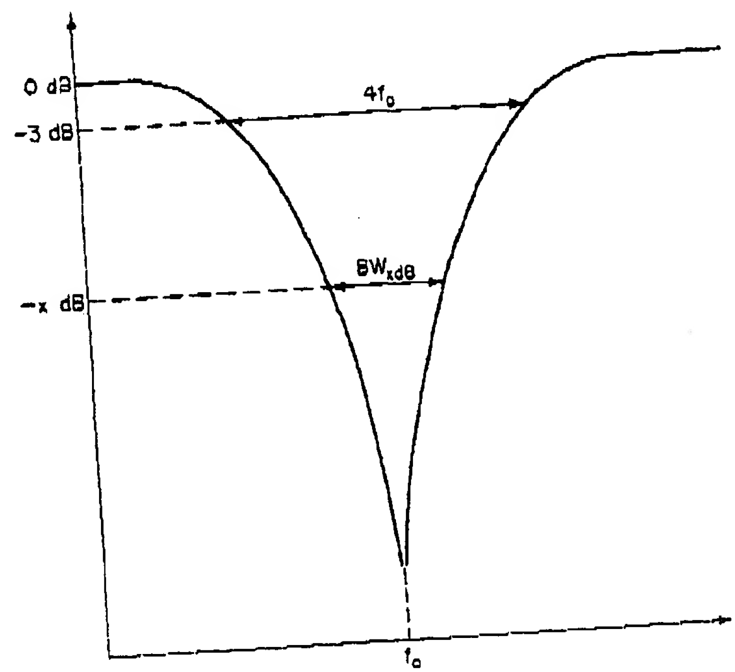


Fig. 6-26 Frequency response of twin-T.

[2] Since the source and load are always finite, the value of R_1 should be in the vicinity of $\sqrt{R_s R_L}$, provided that the ratio R_L/R_s is in excess of 10.

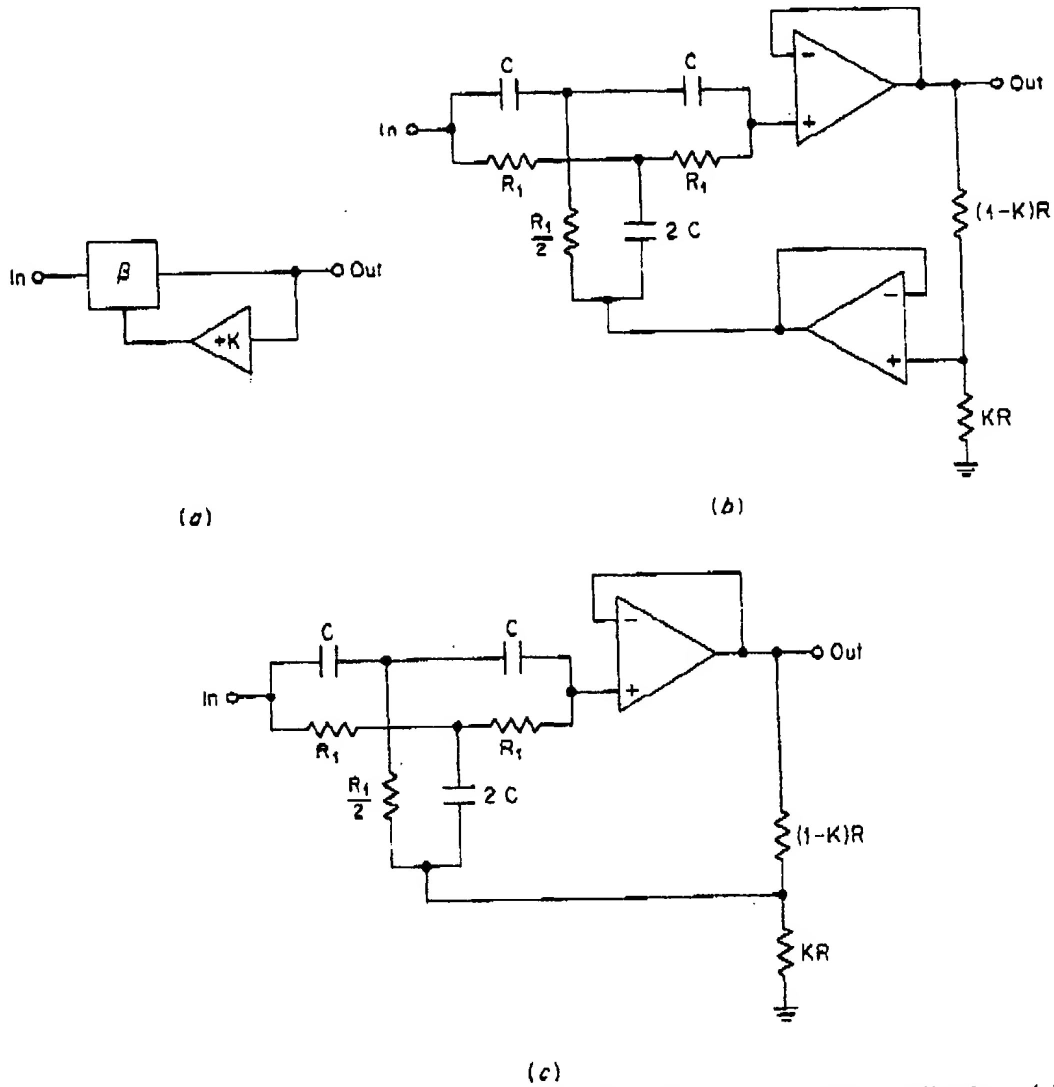


Fig. 6-27 Twin-T with positive feedback: *(a)* block diagram; *(b)* circuit realization; *(c)* simplified configuration $R_1 \gg (1-K)\,R$.

Twin-T with Positive Feedback The twin-T has gained widespread usage as a general-purpose null network. However, a major shortcoming is a fixed Q of ¼. This limitation can be overcome by introducing positive feedback.

The transfer function of the circuit of figure 6-27*a* can be derived as

$$T(s) = \frac{\beta}{1 + K(\beta - 1)} \qquad (6\text{-}77)$$

If β is replaced by equation (6-75), the transfer function of a twin-T, the resulting circuit transfer function expression becomes

$$T(s) = \frac{s^2 + \omega_0^2}{s^2 + 4\omega_0(1-K)s + \omega_0^2} \qquad (6\text{-}78)$$

The corresponding Q is

$$Q = \frac{1}{4(1-K)} \qquad (6\text{-}79)$$

By selecting a positive K of < 1 and sufficiently close to unity, th circuit Q can be dramatically increased. The required value of K can be determined by

$$K = 1 - \frac{1}{4Q} \tag{6-80}$$

The block diagram of figure 6-27a can be implemented using the circuit of figure 6-27b, where R is arbitrary. By choosing C and R so that $R_1 >> (1 - K)R$, the circuit may be simplified to the configuration of figure 6-27c, which uses only one amplifier.

The attenuation at any bandwidth is given by

$$A_{dB} = 10 \log \left[1 + \left(\frac{f_0}{Q \times BW_{x\ dB}} \right)^2 \right] \tag{6-81}$$

Equation (6-81) is the general expression for the attentuation of a single band-reject section where the resonant frequency and notch frequency are identical (i.e., $f_r = f_\infty$). The attenuation formula can be expressed in terms of the 3-dB bandwidth as follows:

$$A_{dB} = 10 \log \left[1 + \left(\frac{BW_{3\ dB}}{BW_{x\ dB}} \right)^2 \right] \tag{6-82}$$

The attenuation characteristics can also be determined from the frequency-response curve of a normalized $n = 1$ Butterworth low-pass filter (see figure 2-34) by using the ratio $BW_{3\ dB}/BW_{x\ dB}$ for the normalized frequency.

The twin-T in its basic form or in the positive-feedback configuration is widely used for single-section band-reject sections. However, it suffers from the fact that tuning cannot be easily accomplished. Tight component tolerances may then be required to ensure sufficient accuracy of tuning and adequate notch depth. About 40- to 60-dB rejection at the notch could be expected using 1% components.

Example 6-9

REQUIRED: Design a single null network having a center frequency of 1000 Hz and a 3-dB bandwidth of 100 Hz. Also determine the attenuation at the 30-Hz bandwidth.

RESULT: (*a*) A twin-T structure with positive feedback will be used. To design the twin-T, first choose a capacitance C of 0.01 μF. The value of R_1 is given by

$$R_1 = \frac{1}{2\pi f_0 C} = \frac{1}{2\pi \times 10^3 \times 10^{-8}} = 15.9\ \text{k}\Omega \tag{6-74}$$

(*b*) The required value of K for the feedback network is calculated from

$$K = 1 - \frac{1}{4Q} = 1 - \frac{1}{4 \times 10} = 0.975 \tag{6-80}$$

where $Q = f_0/BW_{3\ dB}$

(*c*) The single amplifier circuit of figure 6-27c will be used. If R is chosen at 1 kΩ, the circuit requirement for $R_1 >> (1 - K)R$ is satisfied. The resulting section is shown in figure 6-28.

(*d*) To determine the attenuation at a bandwidth of 30 Hz, calculate

$$A_{dB} = 10 \log \left[1 + \left(\frac{BW_{3\ dB}}{BW_{x\ dB}} \right)^2 \right] = 10 \log \left[1 + \left(\frac{100\ \text{Hz}}{30\ \text{Hz}} \right)^2 \right] \tag{6-82}$$

$$= 10.8\ \text{dB}$$

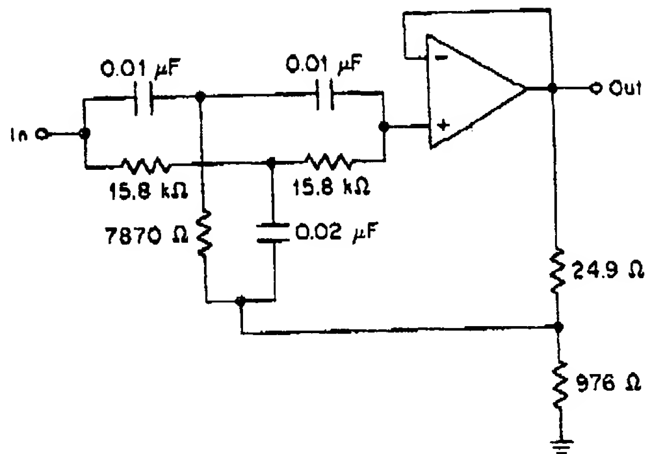


Fig. 6-28 Twin-T network of example 6-9.

Bandpass Structure Null Networks Section 6.2 under Narrow-Band Active Band-Reject Filters showed how a first-order bandpass section can be combined with a summing amplifier to obtain a band-reject circuit for transformed real poles where $f_r = f_\infty$. Three types of sections were illustrated in figure 6-23 corresponding to different Q ranges of operation. These same sections can be used as null networks. They offer more flexibility than the twin-T, since the null frequency can be adjusted to compensate for component tolerances. In addition the DABP and biquad circuits permit Q adjustment as well.

The design formulas were given by equations (6-67) through (6-73). The values of f_r and Q in the equations correspond to the section center frequency and Q, respectively.

Frequently a bandpass and band-reject output are simultaneously required. A typical application might involve separation of signals for comparison of in-band and out-of band spectral energy. The band-reject sections of figure 6-23 can each provide a bandpass output from the bandpass section along with the null output signal. An additional feature of this technique is that the bandpass and band-reject outputs will track.

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Active Filter Design Handbook

For Use with Programmable Pocket Calculators and Minicomputers

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and
P. Horn
Institut für Fernmeldetechnik
ETH, Zürich

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7. BR-LQ (BAND REJECT LOW Q)

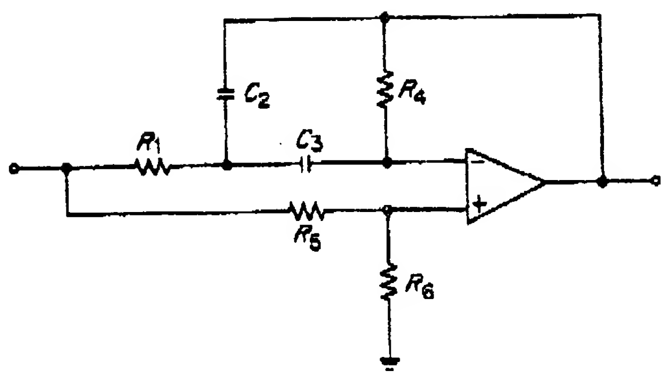

Fig. 5-7

$$T(s) = K\frac{s^2 + \omega_p^2}{s^2 + (\omega_p/q_p)s + \omega_p^2} \qquad (7a)$$

$$\omega_p^2 = \frac{1}{R_1C_2C_3R_4} \qquad (7b)$$

$$\frac{1}{R_4C_2} + \frac{1}{R_4C_3} = \frac{1}{R_1C_2}\frac{R_5}{R_6} \qquad (7c)$$

$$q_p = \frac{\sqrt{R_4/R_1}}{\sqrt{C_2/C_3} + \sqrt{C_3/C_2}} \qquad (7d)$$

$$K = \frac{R_6}{R_5 + R_6} \qquad (7e)$$

$$\mathrm{GSP} = q_p\sqrt{\frac{R_4C_3}{R_1C_2}} \qquad (7f)$$

. BR–MQ (BAND REJECT MEDIUM Q)

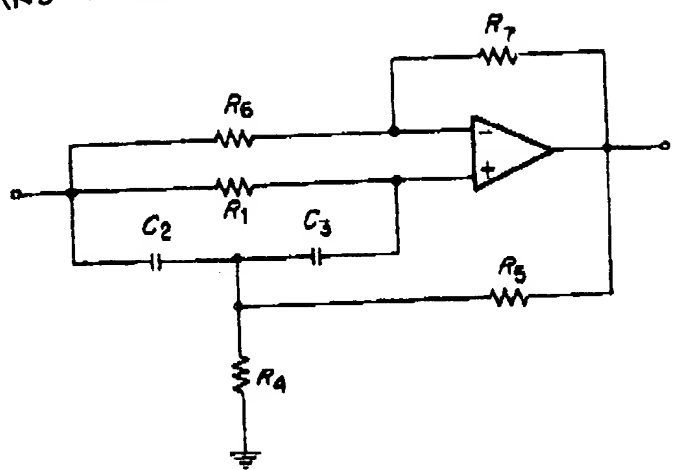

Fig. 5-13

$$T(s) = \frac{s^2 + \omega_p^2}{s^2 + (\omega_p/q_p)s + \omega_p^2} \qquad (13a)$$

$$R_p = R_4 \| R_5 \qquad (13b) \qquad\qquad \omega_p^2 = \frac{1}{R_1 C_2 C_3 R_p} \qquad (13c)$$

$$\frac{1}{R_1 C_2} + \frac{1}{R_1 C_3} = \frac{1}{R_p C_2}\frac{R_7}{R_6} \qquad (13d)$$

$$q_p = \frac{\omega_p}{1/R_1C_2 + 1/R_1C_3 + 1/R_4C_2 - (1/R_5C_2)(R_7/R_6)} \qquad (13e)$$

$$\text{GSP} = q_p \frac{R_p}{R_5}\left(1 + \frac{R_7}{R_6}\right)^2 \sqrt{\frac{R_1 C_3}{R_p C_2}} \qquad (13f)$$

Tuning: (1) f_p with R_1, (2) $|T(f_p)| = 0$ with R_4, (3) q_p with R_7

20. BR–HQ (BAND REJECT HIGH Q)

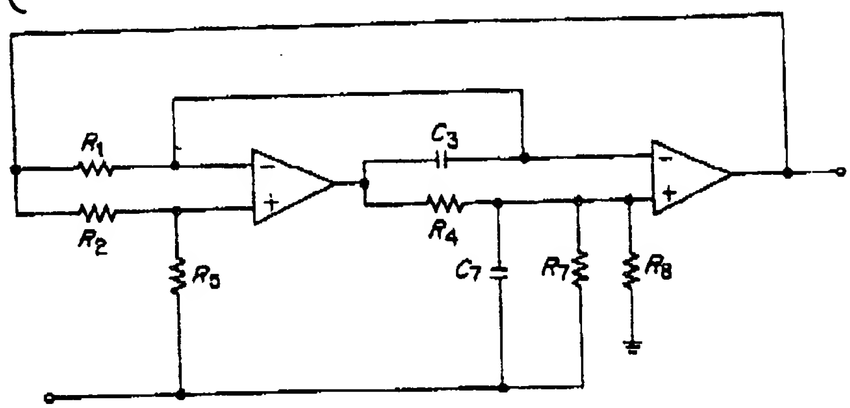

Fig. 5-20

$$T(s) = \frac{s^2 + \omega_p^2}{s^2 + (\omega_p/q_p)s + \omega_p^2} \qquad (20a)$$

$$\omega_p^2 = \frac{R_2}{R_1 R_4 R_5 C_3 C_7} \qquad (20b)$$

$$q_p = \omega_p C_7 \frac{R_7 R_8}{R_7 + R_8} \qquad (20c)$$

$$R_2 R_7 = R_5 R_8 \qquad (20d)$$

Tuning: (1) f_p with R_4, (2) $|T(j_p)| = 0$ and q_p with R_7 and R_8 (iterative)

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Attorney: Sanders N. Hillis, Atty. Reg. No. 45,712

PATENT
Case No. 11336/108 (P00042US)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	)	Group Art Unit: 2816
Gerald R. STANLEY	)	Examiner: T. Cunningham
Serial No.: 09/748,609	)	
Filed: December 26, 2000	)	
For: ACTIVE ISOLATED-INTEGRATOR LOW-PASS FILTER WITH ATTENUATION POLES	)	

TRANSMITTAL OF NEW FORMAL DRAWING

The Commissioner for Patents
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Sir:

Applicant submits herewith new formal drawing FIG. 6 to the Official Draftsperson.

Respectfully submitted,

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Attorney Reg. No. 45,712

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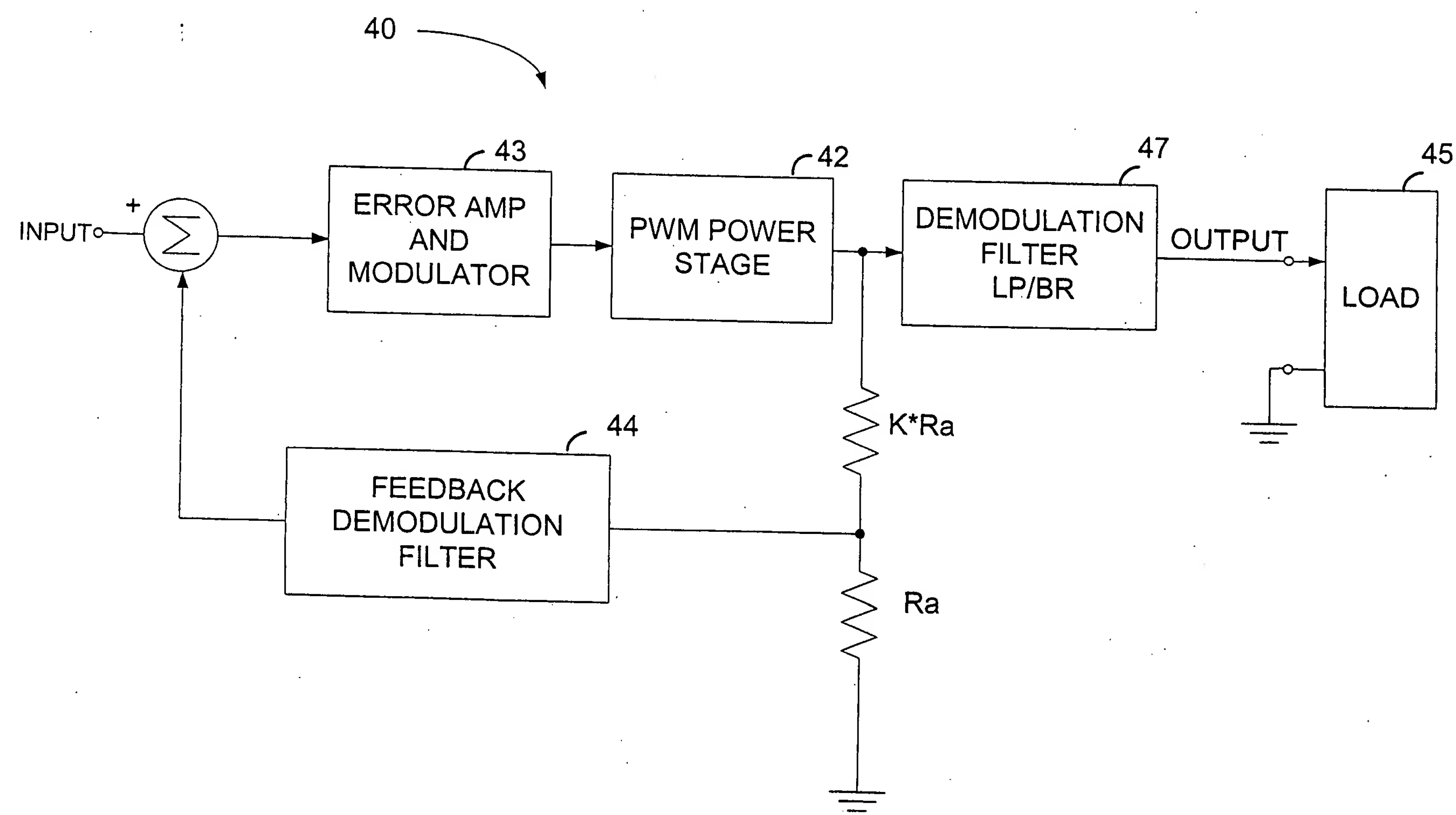
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ERROR AMP
AND
MODULATOR
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PWM POWER
STAGE
47
DEMODULATION
FILTER
LP/BR
OUTPUT
45
LOAD
44
FEEDBACK
DEMODULATION
FILTER
K*Ra
Ra

FIG. 6